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HYDRO- AND HEMODYNAMIC EFFECTS OF CATHETERIZATION OF VESSELS

III Experiments with a rigid-walled model

L. BJORNO and H. PETTERSSON

Arterial catheterization is necessary for most angiographic examinations and for many pressure and volumetric flow rate measurements in medicine. How much the pressure and the volumetric flow rate in a vessel will be disturbed by the presence of a catheter in the vessel, leading to false measurement values and even to false conclusions, is scantly discussed in the literature (CROWE & KROVETZ 1970, KANAI et coll. 1970, BERÁNEK 1971).

Therefore the influence of catheterization upon pressure and volumetric flow rate in a rigid walled vessel was analysed by means of the mechanical model previously described in Part I (BJORNO & PETTERSSON 1976 a).

Theoretical considerations

The flow in a smooth, concentric annulus formed by an outer tube with an inside diameter d_2 and an inner tube with an outside diameter d_1 may be either laminar or turbulent. The velocity profiles for laminar and turbulent flow of the same volu

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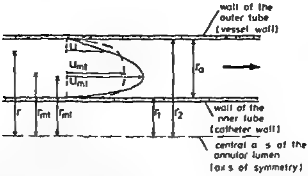


Fig 1 Flow geometry and laminar and turbulent velocity profiles for the same volumetric mean velocity U in the cross section of concentric annulus r_1 – outer radius of the catheter r_2 inner radius of the vessel r_a – equivalent radius expressing the width of the annular lumen ($r_a = r_2 - r_1$) r_{ml} – the radius of the point of maximum flow velocity in laminar flow (u_{ml}) r_{mt} – the radius of the point of maximum flow velocity in turbulent flow (u_{mt}) r – an arbitrary radius corresponding to the arbitrary flow velocity u [$u = u(r)$] —— laminar velocity profile – – turbulent velocity profile

metric mean velocity U in the cross section of such a concentric annulus appears in Fig 1

Laminar flow The differential equation for laminar flow in a horizontal concentric annulus is the same as the one for circular tubes (Bjorno 1972) Integration of this differential equation and introduction of the boundary conditions that the flow velocity must be zero at $r = r_1$ (the inner tube wall) and at $r = r_2$ (the outer tube wall) lead to the following equation for the velocity distribution $u = u(r)$ across the annulus for laminar flow

$$u = 2U \frac{r_2^2 - r^2 - 2r_{ml}^2 \ln(r_2/r_1)}{r_2^2 - r_1^2 - 2r_{ml}^2} \quad \text{(m/s)} \tag{1}$$

where r(m) is a radius and where U is the volumetric mean velocity determined by the equation

$$U = \frac{Q}{\pi(r_2^2 - r_1^2)} \quad \text{(m/s)} \tag{2}$$

where Q (m^3/s) is the volumetric flow rate through the annulus r_{ml} is the radius at the point of maximum flow velocity in the laminar annular flow and it is determined by the equation

$$r_{ml} = \sqrt{\frac{r_2^2 - r_1^2}{2 \ln(r_2/r_1)}} \quad \text{(m)} \tag{3}$$

Knowing U from eq (2) the velocity distribution for laminar flow in a given annulus may be determined from eq (1) This velocity profile is given in Fig 1

For steady flow in the annulus the loss in static pressure Δp due to wall friction over an axial distance l may be written (BJORNO)

$$\Delta p = \lambda \frac{l}{d_e} \varrho \frac{U^2}{2} \quad \text{(Pa)} \tag{4}$$

ϱ denotes the density of the flowing fluid and $d_e = d_2 - d_1 = 2(r_2 - r_1)$ is an equivalent diameter expressing the width of the annular lumen with d_2 and d_1 being the inside diameter of the outer tube and the outside diameter of the inner tube respectively λ is the dimensionless friction factor which for laminar flow in the annulus may be written

$$\lambda = \frac{64}{Re} \phi(d_1/d_2) \tag{5}$$

where Re is the Reynolds number of the flow given by

$$Re = \frac{U \, d_e \, \varrho}{\mu} \tag{6}$$

with μ (Pa s) denoting the dynamic viscosity of the fluid

The function $\phi(d_1/d_2)$ may by the use of the shear stress definition together with the eqs (1) and (4) be written

$$\phi(d_1/d_2) = \frac{(1 - d_1/d_2)}{1 + (d_1/d_2) + \{[1 - (d_1/d_2)]/\ln(d_1/d_2)\}} \tag{7}$$

which in the d_1/d_2 region reported in this article leads to values of $\phi(d_1/d_2)$ in the region $1.44 < \phi(d_1/d_2) < 1.50$

Only very small values of d_1/d_2 lead to a strong reduction in $\phi(d_1/d_2)$

For fully developed steady flow in annuli laminar flow should as a rule be expected at Re values below 2 000 However no sharp transition to turbulent flow is to be expected and transition may cover a fairly wide range of Reynolds numbers Due to the influence of the disturbances caused by the flow conditions in the inlet to the annular lumen turbulent flow has been found at Re values down to Re ~ 1 000 and in some tests even lower

Turbulent flow No analytical solutions like the one found for laminar flow in the annulus exists for the turbulent flow case Empirical results form here the foundation

In spite of the fact that the turbulent velocity profile is flat in the vicinity of the maximum velocity u_{mt} (Fig 1) leading to difficulties in the experimental determination of r_{mt} the following empirical equation may be used for determination of r_{mt} of the turbulent velocity profile (KAYS & LEUNG 1963)

$$r_{mt} = [(r_1/r_2)^{0.343} r_2 + r_1]/[1 + (r_1/r_2)^{0.343}] \quad \text{(m)} \tag{8}$$

The loss in static pressure Δp due to wall friction over an axial length l of the smooth concentric annulus may also for turbulent flow be calculated by means of eq. (4). The present experiments have shown the applicability of the following equation for the dimensionless friction factor λ for turbulent flow

$$\lambda = 0.34 \ \mathrm{Re}^{-1/4} \tag{9}$$

which has been used for the calculation of the static pressure in the catheterized vessel model to be compared with the measured pressure values.

Eccentric position of the inner tube. As concentric annuli hardly excist in clinical catheterization of arteries, the influence of eccentricity of the inner tube (the catheter) must be taken into consideration. Eccentricity causes the local friction coefficient to vary circumferentially around the inside and the outside annulus walls, leading to an increased volumetric flow rate through the annulus and to a lower everage loss in static pressure. Empirical curves for the reduction in λ for increasing eccentricity of the annulus may for laminar flow be found in the work by SNYDER & GOLDSTEIN (1965) and for turbulent flow in the work by JONSSON & SPARROW (1966). Their statements will not be repeated here. It will only be mentioned that the eccentricity of the catheter close to the inlet in the branch vessel of the model led to measured volumetric flow rates and static pressures in good agreement with the findings of these authors. The influence of eccentricity is also discussed in section (5).

Experimental Results and Discussion

The shape and dimensions of the vessel model appear in Fig. 2 and its auxiliary equipment and mode of function are described in Part I (BJORNO & PETTERSSON 1976 a).

A series of factors that may influence the static pressure and the volumetric flow rate through the catheterized branch vessel have been analysed. The influence of (1) the length of the catheter introduced into the branch vessel, (2) various catheter diameters for fixed branch vessel diameter, (3) various branch vessel diameters for fixed catheter diameter, (4) the dynamic viscosity of the test liquid, and (5) the mode of catheterization.

1. Influence of the length of the catheter. Through a hole in the main vessel at the point g_1 (opposite to the branch vessel, Fig. 2) catheters of various diameters were introduced into the branch vessel. This mode of catheterization, though unrealistic in patients, opened up the possibility of establishing a concentric annulus by having the catheter axis coincide with the branch vessel axis. The catheter was introduced into the branch vessel up to a distance $l = 10$ cm from the inlet, and the static pressure was measured at positions with a mutual distance of 1 cm along the branch vessel (Fig. 2). The tests for each catheter diameter were performed for various volu

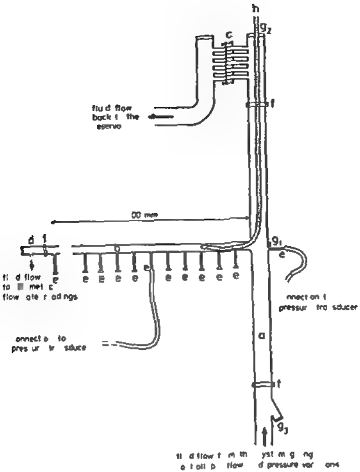


Fig 2 The vessel model used in the experiments of the influence of catheterization on static pressure and volumetric flow rate through a branch vessel b connected to a main vessel a a) Main vessel with inside diameter 10 0 mm and outside diameter 13 mm b) Branch vessel at right angles to the main vessel The inlet corners are smoothed and rounded with a radius equal to the branch vessel radius The branch vessel is interchangeable c) Peripheral resistance in the main vessel consisting of 5 soft plastic tubes their lumina are varied by means of a clamping screw d) Peripheral resistance of the branch vessel consisting of a 4 cm long tube with a closed end This tube is made of the same material and it has the same radial dimensions as the branch vessel The peripheral resistances are interchangeable and the flow resistance is brought about by means of a hole in the tube wall A series of peripheral resistances were used having hole diameters in the range 0 6 to 4 0 mm thus making it possible to supply the branch vessel with a flow resistance appropriate for the specific flow conditions considered in the branch vessel e) Hypodermic needles for static pressure measurements Inside diameter 0 4 mm and outside diameter 0 8 mm Static pressure is measured with the opening of the needles flush mounted to the vessel wall The needles are via polyethylene tubes connected to pressure transducers. f) Plastic tubes fitted over the joints between the vessel sections, in order to avoid any flow disturbing irregularities of the inner wall at the joints g_1–g_3) Points for introduction of catheters into the vessel model h) Catheter inserted into the branch vessel The catheter is introduced in the counter flow direction of the main vessel ⟶ Direction of the fluid flow

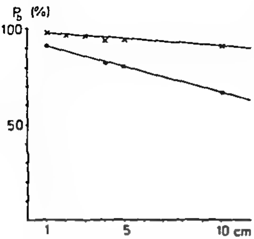


Fig. 3 Static pressure p_b in the branch vessel as a function of the length l of the introduced catheter. p_b is measured and calculated for two volumetric flow rates (Q_e = 400 ( ) and 800 (●) ml min) and for d_1 = 2.4 mm and d_2 = 4.1 mm. p_b is expressed in per cent of the static pressure p at the inlet to the branch vessel (p = 1.0 10³ Pa ~90 mmHg) —Calculated course

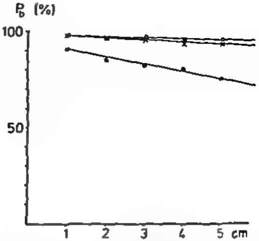


Fig. 4 Static pressure p_b in the branch vessel as a function of the length l of the introduced catheter. p_b is measured and calculated for three different catheter diameters d_1 = 1.6 ( ) 2.4 ( ) and 3.2 (●) mm. The vessel diameter d_v = 4.1 mm. Q = 400 ml min. p_b is expressed in per cent of the static pressure p_e in the main vessel at the inlet to the branch vessel (p 12.0 10³ Pa ~90 mmHg) —Calculated course

metric flow rates Q_0, where Q_0 denotes the volumetric flow rate through the branch vessel before catheterization. The static pressure p_e in the main vessel was kept constant at p_e = 12 10³ Pa ~ 90 mmHg. The dynamic viscosity μ of the test liquid (tap water at 30 C) was kept constant during the tests μ = 0.9 cP measured by means of an Ostwald viscosimeter.

Insertion of the catheter reduced the volumetric flow rate through the branch vessel. This reduced volumetric flow rate is in the following denoted Q_b.

The experimental results and the calculated values of the static pressure along the branch vessel for two different volumetric flow rates are compared in Fig. 3. The diameters of the catheter and of the branch vessel were 2.4 mm and 4.1 mm respectively. A length *l* = 10 cm of the catheter was introduced in the branch vessel *before* the measurements in Fig. 3 were carried out.

Due to the fact that Q_b is a constant for each curve in Fig. 3 the volumetric mean velocity is a constant (eq. 2) and the Re number and thus the λ value are constants (eqs. 6 and 9). Therefore the static pressure will be reduced linearly with the length l along the catheter introduced into the branch vessel in accordance with eq. 4.

For the calculation of the static pressure values along the branch vessel it was assumed that the annular flow was fully developed. This is an approximation; a distance from the inlet of about 30 times the annular diameter is normally considered necessary to establish a fully developed annular flow.

However, a good agreement between the experimentally found and the theo-

retically calculated results has been obtained This means that the relatively simple fluid mechanics equations given in Theoretical considerations may be applied for calculation of the pressure course in catheterized vessels Some minor deviations from the linear pressure course observed at positions 2 and 3 at the line marked $Q_0 = 800$ ml/min may be due to not fully developed turbulent velocity profiles in the annulus

A strong deviation from the linear pressure course was found only between the *inlet and the first measurement position 1 cm from the inlet to the branch vessel* The very complicated 3 dimensional flow conditions in the inlet to the branch vessel demands more sophisticated theoretical methods for their description

It is a general feature in all experiments performed that the introduction of the catheter through the branch vessel inlet leads to a strong reduction in static pressure and in volumetric flow rate compared with the reduction along the catheter further distal in the branch vessel

A relatively stronger decrease in static pressure was observed at the high volumetric flow rates in agreement with eq 4 where U will increase for an increase in Q_0

Similar measurements were performed after introduction of the catheters 1 to 9 cm into the branch vessel and the results were principally equal to those given in Fig 3

2 Influence of various catheter diameters for fixed branch vessel diameter A series of experiments was performed in order to investigate the influence of the catheter diameter on the static pressure in and the volumetric flow rate through the branch vessel The branch vessel diameter was kept constant d =4 1 mm All tests were performed using a test liquid (tap water) with the dynamic viscosity $\mu = 0\ 9$ cP The mode *of catheterization was the same as the one described in section 1 leading* to a concentric annulus in the branch vessel A length $l = 5$ cm of the catheters were introduced into the branch vessel and were kept at that position during the measurements Experimental and theoretical values of the static pressure in the annulus as a *function* of the length *l* of the introduced catheter are given in Fig 4 The good agreement between theory and experiment emphasizes the applicability of the equations given in Theoretical considerations for calculation of the pressure course in a catheterized vessel when catheters of various diameters are used

It is evident from Fig 4 that a change in catheter diameter leads to a changed pressure course in the catheterized vessel with the greatest absolute loss in static pressure obtained for $d_1 = 3\ 2$ mm i e for the smallest annular lumen

The introduction of a catheter also influences the volumetric flow rate through the branch vessel by reducing the volumetric flow rate from Q_0 before the catheterization to Q_b during the catheterization As the catheter tip had a fixed position at $l = 5$ cm Q_b was kept constant for each individual catheter tested and the Q_b values were $Q_b = 395$ ml/min for $d_1 = 1\ 6$ mm $Q_b = 390$ ml/min for $d_1 = 2\ 4$ mm and $Q_b = 370$ ml/min for $d_1 = 3\ 2$ mm This change of Q_b between the curves leads to a change in the

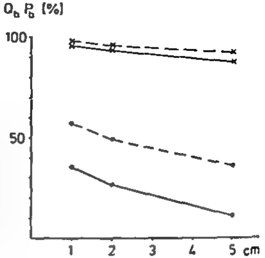


Fig. 5 Measured volumetric flow rate Q_b (---) and static pressure p_b (——) in the branch vessel as a function of the length l of the catheter introduced for two different branch vessel diameters $d_2 = 4.1$ ( ) and 3.1 (●) mm. Measurement of the static pressure was performed at a position 6 cm from the branch vessel inlet. Catheter diameter was 2.4 mm. Q_b is expressed in per cent of $Q = 420$ ml/min and p_b in per cent of the static pressure p_0 in the main vessel at the inlet to the branch vessel ($p = 12.0 \cdot 10^3$ Pa ~90 mmHg)

volumetric mean velocity U between the curves but to constant U for each curve thus leading to a linear dependence of p_b and l for each d_1 value in accordance with eq. 4.

The slope of the lines in Fig. 4 representing the gradient $\Delta p_b/\Delta l$ increases with decreasing annular lumen.

3. *Influence of various branch vessel diameters for fixed catheter diameter.* The catheter diameter d_1 was kept constant during each measurement series. Some results obtained during the series represented by $Q_0 = 420$ ml/min, $p_0 = 12.0 \cdot 10^3$ Pa ~90 mmHg and $d_1 = 2.4$ mm appear in Fig. 5, which gives the volumetric flow rate Q_b and the static pressure p_b in the catheterized vessel for two different branch vessel diameters d. p_b is measured 6 cm from the inlet, and it is measured for each cm of catheterization of the vessel (note the difference from sections 1 and 2, where the position of the catheter was fixed for each series of measurements). Due to the fact that Q_b decreases with increasing introduced length l of the catheter, no linear dependence between p_b and l is found. The strongest reduction in Q_b and in p_b occurred by the catheterization of the branch vessel with the diameter $d_2 = 3.1$ mm, i.e. for the smallest annular lumen.

From Fig. 5 it may be seen that the local values of the volumetric flow rate Q_b, i.e. Q values corresponding to the same introduced length l of the catheter, with decreasing annular lumen leads to increasing gradients $\Delta p_b/\Delta l$ in the static pressure. It may seem paradoxical that the pressure gradient is greater for lower volumetric flow rate. However, it is due to the fact that reduced annular lumen diameter d leads to reduced Q, but at the same time to an increase in U and in Re giving a decrease in λ, but not a decrease strong enough for compensating for the increase in U, which squared according to 4 eq. causes an increase in the pressure gradient $\Delta p_b/\Delta l$.

Measurements of p_b for various volumetric flow rates Q_b for the same values of d_1 d_2 and l showed a pressure decrease in the branch vessel proportional of Q_b^2 which is in agreement with eq 4 with U inserted from eq 2

Calculations of λ based upon the measured values of the volumetric mean velocity leading to Re numbers in the turbulent flow region showed that λ in the diameter ratio interval investigated ($0.18 < d_1/d < 0.78$) would be independent of this ratio while a significant dependence of λ on $d_a = d - d_1$ was found

The measurements further showed that for both laminar and turbulent flow the volumetric flow rate Q_b will be more strongly influenced by the annular lumen variation than by the pressure gradient $\Delta p_b/\Delta l$ This may be explained for laminar flow by the equation for the volumetric flow rate through an annulus which by the use of eqs 1 and 2 may be written

$$Q_b = \frac{\pi}{8\mu}\,\frac{\Delta p_b}{\Delta l}\left(r_2^4 - r_1^4 + \frac{(r_2^2 - r_1^2)^2}{\ln(r_1/r_2)}\right) \quad (\mathrm{m^3/s}) \tag{10}$$

Eq 10 shows the strongest dependence of Q_b on r_1 and r_2 and a similar argumentation may be used for explaining the same dependence for turbulent flow

4 *Influence of the dynamic viscosity of the test liquid* The dynamic viscosity μ of the test liquids—some glycerine/water mixtures added to tap water—was determined by means of an Ostwald viscosimeter and the test liquid densities were measured by weighing a known volume of the liquids

Measurement of the static pressure loss along the branch vessel before the insertion of the catheter for all liquids tested gave experimental values in close agreement with values calculated by means of eq 4 with $d_a = d_2$ and by the use of the following equation for λ

$$\lambda = \frac{64}{\mathrm{Re}} \quad \text{(for laminar flow)} \tag{11}$$

and

$$\frac{1}{\sqrt{\lambda}} = 0.87 \ln(\mathrm{Re}\sqrt{\lambda}) - 0.8 \quad \text{(for turbulent flow)} \tag{12}$$

The derivation of eqs 11 and 12 may be found in BJORNO (1972)

The catheters were introduced through the hole in the main vessel at point g_1 opposite to the inlet to the branch vessel thus forming a concentric annulus together with the branch vessel

Measurements of the static pressure were performed at a position 20 cm from the inlet to the branch vessel During all tests with liquids of various viscosity the volumetric flow rate Q_0 through the branch vessel before catheterization was kept constant ($Q_0 = 800$ ml/min) by varying the peripheral resistance of the branch vessel ($\mu = 6.5$ cP gave $Q_0 = 780$ ml/min) The static pressure p_0 in the main vessel at the inlet to the branch vessel was also kept constant during the tests ($p_0 = 12.0 \cdot 10^3$ Pa

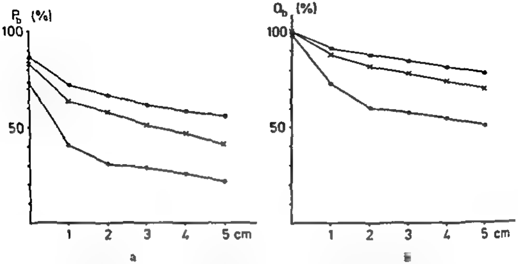
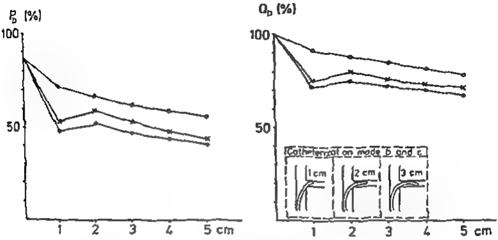


Fig 6 a) Static pressure p_b as a function of the length l of the catheter introduced into the branch vessel measured at a position 20 cm from the branch vessel inlet for three different dynamic viscosities μ of the test liquid $d_1 = 3.2$ mm and $d_2 = 4.1$ mm p_b is expressed in per cent of the static pressure p measured in the main vessel at the inlet to the branch vessel ($p_o = 12.0 \cdot 10^3$ Pa ~ 90 mmHg) b) Volumetric flow rate Q_b $d_1 = 3.2$ mm and $d_2 = 4.1$ mm Q_b is expressed in per cent of the volumetric flow rate Q_o in the branch vessel without introduced catheter ($Q_o = 800$ ml/min) μ 0.9 (○) 2.3 ( ) and 6.5 (●) cP

($\sim$90 mmHg) Fig 6 illustrates the measured static pressure p_b and volumetric flow rate Q_b respectively as a function of the length l of the catheter introduced into the branch vessel for three different dynamic viscosities μ of the test liquid These tests were performed for $d_1 = 3.2$ mm and $d_2 = 4.1$ mm

The introduction of the catheter leads to a decrease in Q_b a decrease being more marked with increasing viscosity This leads to a decrease in the volumetric mean velocity and a decrease in the Re number The Re number is further decreased by increasing viscosity thus leading to increasing values of λ Depending upon the local reduction in Q_b the local pressure gradient $\Delta p_b/\Delta l$ will then be increasing or decreasing This explains the irregularities in Fig 6a Calculations by means of eq 4 of the local variation in $\Delta p_b/\Delta l$ based upon the local variation in Q_b show a fair agreement with the measured values given in Fig 6a for all three viscosities tested From Fig 6 it may also be seen that the catheterization through the branch vessel inlet leads to the strongest reduction in p_b and Q_b a reduction which increases with increasing liquid viscosity When the catheter tip has passed position 1 (l = 1 cm) the reduction in p_b and Q_b decreases and a smaller pressure and volumetric flow rate gradient than at the inlet between position 0 and 1 will be obtained This is in agreement with the results reported in section 1

A series of experiments was performed in order to investigate if prospective deviations between the viscosity of blood (hematocrit value of 40 % and 53 % and tempera



a b

Fig 7 a) Static pressure p_b in the branch vessel as a function of the length l of the catheter introduced into the branch vessel measured at a position 20 cm from the inlet and for three different modes of catheterization p_b is expressed in per cent of the static pressure p_0 in the main vessel at the inlet to the branch vessel ($p_0 = 12.0 \cdot 10^3$ Pa ~ 90 mmHg) $d_1 = 3.2$ mm and $d_2 = 4.1$ mm, $\mu = 0.9$ cP a (○) = the pressure course when the catheter is introduced from point ■ the catheter being centrally positioned in the branch vessel b (×) = the pressure course when the catheter is introduced from point g i e in counter flow direction in the main vessel ■ (●) = the pressure course when the catheter is introduced from point g i e in the flow direction in the main vessel b) Volumetric flow rate Q_b Q_b is expressed in per cent of the volumetric flow rate Q in the branch vessel without introduced catheter ($Q_0 = 800$ ml/min) $d_1 = 3.2$ mm and $d = 4.1$ mm $\mu = 0.9$ cP The approximate position of the catheter is given after 1 2 and 3 cm catheterization of the branch vessel when mode (b) (counter flow in the main vessel) and (c) (following the flow direction of the main vessel) was used

ture 37 C) and the viscosity of the test liquids ($\mu = 4$ cP–6.5 cP) existed The result was that blood behaved like a Newtonian liquid at the shear rates characteristic for the catheterization experiments performed

5 *Influence of the mode of catheterization* Catheterization through the main vessel wall at point g_1 opposite the inlet to the branch vessel is unrealistic in medicine Counter flow catheterization (Fig 2) or catheterization in the flow direction of the main vessel into the branch vessel are the normal procedures Fig 7 gives the measured values of p_b and Q_b as a function of the length l of the catheter introduced into the branch vessel for three different modes of catheterization namely (a) through the main vessel wall from point g_1 (b) counter flow in the main vessel from point g and (c) in the flow direction in the main vessel from point g_3 In Fig 7 b is also illustrated the approximate position of the catheter for the first 3 cm of catheterization (mode a and b) The measurements of p_b were performed at a position 20 cm from the branch vessel inlet For the experimental results given in the Fig 7 the following data were kept constant $d_1 = 3.2$ mm $d = 4.1$ mm $\mu = 0.9$ cP $P_0 = 12.0 \cdot 10^3$

Pa ~90 mmHg $Q_0 = 800$ ml/min A strong influence of the mode of catheterization was demonstrated the greatest reduction appearing in Q_b and p_b for catheterization in the flow direction through the main vessel into the branch vessel As previously found the catheterization through the inlet—between position 0 and position 1—led to the strongest reduction in Q_b and p_b

The increase in p_b and Q_b between position 1 and 2 for the curves (b) and (c) may probably be due to eccentricity of the catheter position in and just after the inlet to the branch vessel As mentioned in Theoretical considerations the eccentricity of the annulus will lead to increasing pressure and volumetric flow rate in the catheterized vessel From Fig 7 b it is seen that the catheter transversed the branch vessel lumen about diagonally when the tip had reached position 1 while it was close to the vessel wall when the tip had reached position 2 This contact between the catheter and the vessel wall (100 % eccentricity) may cause the observed increase in p_b and Q_b Obviously the position of the catheter in the branch vessel lumen also should be dependent on a possible preformation

The difference between the measured values of p_b and Q_b in mode (b) and (c) may be due to the different influences of the two modes of catheterization on the stagnation pressure and the velocity distribution in the main vessel at the inlet to the branch vessel A clearer understanding of the cause of the observed deviation between mode (b) and mode (c) may be found through a more detailed investigation of the very complicated 3-dimensional flow at the branch vessel inlet

The measurements of volumetric flow rates Q_b and static pressures p_b for other Q_0 values and d_i values gave the same course as the curves in Fig 7 The deviations between the modes (b) and (c) together with the increase in p_b and Q_b between position 1 and 2 were yet less marked at lower volumetric flow rates or greater annular lumina which is in agreement with previous results showing that the reduction in volumetric flow rate and static pressure would be smaller for lower Q_0 values or for higher d_i values All tests indicated that catheterization mode (c) would lead to the lowest values of Q_b and p_b

Clinical Applicability

In the experiments reported the static pressure in the main vessel was kept at 12 0 to 18 6 10^3 Pa (~90–140 mmHg) i e normal mean blood pressure in man Also the vessels and the catheters were of dimensions usual in medicine But some values of the viscosity of the liquid and of the volumetric flow rate Q_0 through the branch vessel exceeded the range in clinical conditions to ascertain that the results found were valid at all flow conditions that may be reasonable in clinics

In order to obtain information of the hydrodynamic effects of arterial catheterization under conditions more similar to those in clinical practice the following tests were performed

In branch vessels with various diameters d_2 catheters of various outer diameters d_1 were introdued to a length $l = 3$ cm from the inlet The catheterization was per formed both counter flow and in the flow direction of the main vessel The pressure p_0 in the main vessel varied between 12 0 and 18 6 10^3 Pa (~90–140 mmHg) and the volumetric flow rate Q_0 through the uncatheterized vessel varied between 200–1 120 ml/min The dynamic viscosity of the test liquid was = 4 0 cP (corresponding to blood with hematocrit about 40 %) The static pressure p_b in the branch vessel was measured at a position [illegible] cm from the inlet and expressed in per cent of p_0 The volumetric flow rate Q_b through the catheterized vessel was measured and expressed in per cent of Q_0

For d = 6 mm $p_0 = 12\,0 \; 10^3 - 18\,6 \; 10^3$ Pa Q_0 900–1 120 ml/min it was found that the introduction of a catheter of diameter $d_1 = 3\,5$ mm to a length $l = 3$ cm into the branch vessel decreased p_b less than 10 per cent This limit was not exceeded in any of the test series represented by

$l = 3$ cm $d_1 = 2\,4$ mm $d_2 = 4\,1$ mm $p_0 = 12\,0 - 18\,6 \; 10^3$ Pa $Q_0 = 400$–520 ml/min

and

$l = 3$ cm $d_1 = 1\,6$ mm $d = 3\,1$ mm $p_0 = 12\,0 - 18\,6 \; 10^3$ Pa $Q_0 = 200$–245 ml/min

The effect on Q_b was less than the corresponding effect on p_b in agreement with the previous results

No significant difference was found between the catheterization modes in the three test s ries where the 10 % limit was controlled

The values of Q_0 in these test series should for each d be regarded as very high compared with values commonly found under clinical conditions For lower Q_0 the effect of the catheter would have been even less

The experiments reported here were performed in rigid walled vessels In elastic walled vessels a tendency exists to less reduction in mean pressure and mean volu metric flow rate caused by catheterization than in rigid walled vessels of the same dimensions (Part II BJORNO & PETTERSSON 1976 b)

Thus if the results reported here are transferable to clinical conditions the effects on mean pressure and mean volumetric flow rate of catheterization with normal catheters in normal arteries leaving the aorta should be small However catheteriza tion over stenoses may give rise to effects of greater magnitude due to the fact that the volumetric mean velocity may be high in stenoses

In all the experiments steady flow has been used However in steady flow through a vessel the catheter produced changes in static pressure and volumetric flow rate are in a percental agreement with the changes in static mean pulse pressure and volumetric mean flow rate for pulsatile flow in the same vessel (Part II BJORNO & PETTERSSON 1976 b) Thus the results are directly transferable to the mean values in pulsatile flow The physical properties of the test liquids and blood were equal under the test condition (section 4)

Thus the results should clarify some of the hemodynamic effects of arterial catheterization under clinical conditions

Conclusions and Medical Considerations

On the basis of the experimental results and the theoretical analysis the following conclusions may be drawn

(1) A good agreement exists between the experimentally found and the theoretically calculated values of the static pressure and the volumetric flow rate in catheterized vessels

(2) The static pressure along an introduced catheter is reduced linearly with the length of the catheter This may be of interest in super selective catheterization where a long part of the catheter is introduced into arterial branches with diminishing diameter Pressure measurements by such a procedure may lead to false results

(3) The pressure reduction is increasing for an increase in the diameter d_1 of the catheter or for a decrease of the diameter of the vessel But the friction factor λ and through it the reduction in pressure is highly dependent of the difference $d - d_1$ and nearly independent of the ratio d_1/d_2 i e the ratio is of minor importance while the difference in absolute values between the two diameters is of great importance

(4) The catheter induced percental reduction of the static pressure is greater than the percental reduction of volumetric flow rate This means that during a catheterization of an artery leaving the aorta catheter induced false results of importance in arterial blood pressure measurements may appear before false results of importance in volumetric flow rate measurements

(5) High volumetric flow rates lead to relatively greater catheter induced pressure losses Thus the effect of a catheter can never be judged only from the knowledge of the diameters of the catheter and vessel

(6) It is the catheterization of the branch vessel inlet (the first centimeter) that leads to the strongest reduction of pressure and flow and for the following few centimeters of catheterization the reductions in pressure and volumetric flow rate are less—the pressure and the volumetric flow rate may even increase when the inlet is passed by the catheter tip

(7) The decrease in pressure and blood flow rate is less when the catheter is introduced in the counter flow direction in the main vessel and also when the catheter is placed eccentrically in the branch vessel However these differences are of minor importance in catheterization under clinical conditions

(8) An increase in viscosity of the fluid leads to higher catheter induced losses in pressure and volumetric flow rate

(9) The catheter induced decrease in pulse mean pressure and mean volumetric flow rate should be small when catheters of normal dimensions are used in normal arteries However a relatively greater effect should be expected when stenoses are catheterized This will be reported subsequently

SUMMARY

An experimental and a theoretical investigation has been performed on some essential factors influencing the volumetric flow rate through and the static pressure in a catheterized rigid walled vessel model These factors comprise (a) the length of the catheter introduced into the vessel (b) the catheter diameter (c) the vessel diameter (d) the dynamic viscosity of the liquid and (e) the mode of catheterization Theoretical expressions for pressure and volumetric flow rates have been observed for laminar and turbulent flow in even concentric annuli and the influence of eccentricity is discussed A good agreement found between the experimentally and the theoretically obtained values of static pressure and the volumetric flow rate in catheterized vessels elucidates a series of features of interest for catheterization praxis and it emphasizes the applicability of relatively simple fluid mechanical equations in flow conditions of medical interest

ZUSAMMENFASSUNG

Eine theoretische und experimentelle Untersuchung uber einige wichtige Faktoren welche die volumetrische Durchflussgeschwindigkeit durch und den statischen Druck in einem katheterisierten Gefassmodell mit einer starren Wand beeinflussen wurde vorgenommen Diese Faktoren umfassen a) die Lange des in das Gefass eingefuhrten Katheters b) den Diameter des Katheters c) den Diameter des Gefasses d) die dynamische Viskosität der Flussigkeit und e) die Art der Katheterisierung Theoretische Ausdrucke fur den Druck und die volumetrischen Flussgeschwindigkeiten bei laminarer Durchstromung und turbulenter Durchstromung wurden in gleichmassigen konzentrischen Ringen untersucht und der Einfluss der Exzentrizitat diskutiert Die gefundene gute Übereinstimmung zwischen den experimentell und den theoretisch erhaltenen Werten des statischen Drucks und der volumetrischen Durchflussgeschwindigkeit in den katheterisierten Gefassen lassen eine Reihe von fur die Praxis der Katheteruntersuchung interessante Faktoren erkennen Es wird die Anwendbarkeit relativ einfacher Flussigkeits mechanischer Gleichungen unter Durchflussbedingungen von medizinischem Interesse hervorgehoben

RÉSUME

Les auteurs ont fait une recherche expérimentale et théorique sur certains facteurs essentiels qui influent sur le taux de debit volumetrique et sur la pression statique dans un modele de vaisseaux à parois rigides cathétérisé Ces facteurs comprennent (a) la longueur du cathéter introduit dans le vaisseau (b) le diamètre du cathéter (c) le diametre du vaisseau (d) la viscosite dynamique du liquide et (d) le mode de cathétérisme Ils ont etabli des expressions théoriques pour les taux de pression et de debit volumétrique pour un écoulement laminaire et turbulent dans des anneaux réguliers concentriques et ont étudie l influence de l excentricite Ils ont trouve une bonne concordance entre les valeurs de la pression statique calculees theoriquement et mesurees expérimentalement le taux de debit volumétrique dans des vaisseaux cathetérisés explique une série de caractères intéressants pour la pratique du catheterisme Il fait ressortir la possibilité d appliquer des équations relativement simples de mecanique des fluides dans des conditions de debit d intéret médical

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FROM THE DEPARTMENTS OF UROLOGY AND DIAGNOSTIC RADIOLOGY MALMÖ ALLMÄNNA SJUKHUS S 14 01 MALMÖ SWEDEN

HYDRO- AND HEMODYNAMIC EFFECTS OF CATHETERIZATION OF VESSELS

IV Catheterization in the dog

S HELLSTEN and H PETTERSSON

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Previously reported model experiments (BJORNO & PETTERSSON 1976 a b 1977) led to the conclusion that very small effects on mean blood pressure and mean volumetric flow rate should be expected when normal arteries leaving the aorta are selectively catheterized with methods usually recommended Not until the catheter has an outer diameter close to the inner diameter of the artery should a significant effect appear The hemodynamic effect of renal artery catheterization in the dog using catheters of different sizes in renal arteries of different dimensions is now reported

Material and Methods

Four mongrels of both sexes weighing 10 18 24 and 37 kg respectively were used The animals were deprived of food for 12 hours after which they were subjected to the experiments under pentobarbital anaesthesia (Mebumal ACO 25 mg/kg body weight) and endotracheal intubation

Catheterization After percutaneous puncture of the femoral artery a polyethylene catheter (OD 2 2 mm ID 1 45 mm length 40 cm) was introduced into the aorta for

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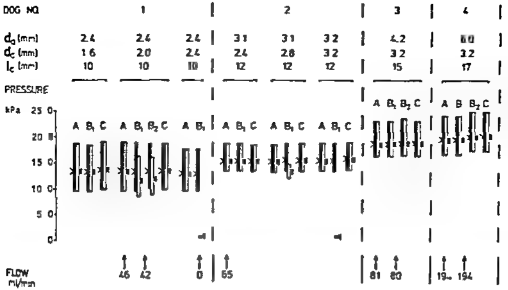


Fig. 2. The pulse peak pressure and the pulse mean pressure in the aorta and the renal artery as well as the mean renal blood flow measured before and during catheterization of the renal artery. d_a = the inner diameter of the renal artery at the site of the tip of the catheter. d_c = the outer diameter of the catheter. l_c = the length of the catheter in the renal artery. ■ = pulse peak pressure in the aorta. □ = pulse peak pressure in the renal artery. ➤ = pulse mean pressure in the aorta. ▲ = pulse mean pressure in the renal artery. A = measurements before the catheterization. B = measurements immediately after catheterization of the renal artery. B_1 = measurements 30 min after catheterization of the renal artery. C = measurements immediately after withdrawal of the catheter.

Experimental procedure. Following introduction of the catheters into the aorta and the renal artery the anaesthetized dog was placed on the roentgen couch and was allowed to rest for 30 min to reach a circulatory steady state. The positions of the catheters were adjusted under fluoroscopic control. Other catheters were introduced into the aorta via the femoral artery and were used for selective catheterization of the renal artery. These catheters had an outer diameter of 1.6, 2.0, 2.4, 2.8 and 3.2 mm, respectively. The smallest one was used first and then successively the wider catheters. They were left in the artery for various times with continuous pressure reading in the renal artery and in the abdominal aorta. The experimental setup is illustrated in Fig. 1.

Blood flow measurements were performed before and during the catheterization of the renal artery. Before the first catheterization, during the catheterization and after the last one contrast medium was injected into the aorta. From the films the inner diameter of the renal artery was calculated, as well as the exact position of the catheter in the renal artery. As the diameter of the catheter in the renal artery was known, the degree of magnification could be determined and hence the exact absolute value of the diameter of the renal artery.

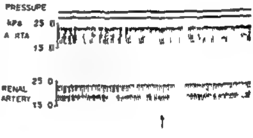


Fig 3 Aortography and blood pressure curve in dog No 4 a) The catheter with outer diameter 3.2 mm in place in the renal artery b) Aortography with the catheter in the same position c) Aortic and renal arterial blood pressure curves → denotes the moment of catheterization of the renal artery

Results

In dog No 1 (body weight 10 kg kidney weight 25 g diameter of the renal artery 2.4 mm renal blood flow before catheterization 45 ml/min) the smallest catheter had no effect on renal blood pressure (Fig 2) The catheter with outer diameter 2.0 mm induced a moderate decrease of the mean pressure and a very slight decrease of renal blood flow The catheter with outer diameter 2.4 occluded the renal artery After removal of this catheter renal blood flow was not re-established because of thrombotic occlusion of the main renal artery and its branches

In dog No 2 (body weight 18 kg kidney weight 40 g diameter of the renal artery 3.1 mm and renal blood flow before catheterization 65 ml/min) the catheter with outer diameter 2.4 had no effect on renal blood pressure while the catheter with outer diameter 2.8 mm induced a slight decrease of the pressure and the catheter with outer diameter 3.2 mm occluded the artery (Fig 2) After removal of this catheter the renal blood pressure and blood flow were re-established

In these two dogs the effect on the systolic pressure was greater than on the diastolic pressure In dog No 2 the percental reduction of the pulse peak pressure was much greater than that of the pulse mean pressure while in dog No 1 the percental reduction of the pulse peak pressure and pulse mean pressure was about the same In dog No 1 the percental decrease of the mean pressure was greater than that of the mean renal blood flow

In the other two dogs Nos 3 and 4 body weight 24 and 37 kg, kidney weight 70 and 105 g diameter of renal artery 4.2 and 6.0 mm renal blood flow before catheteri

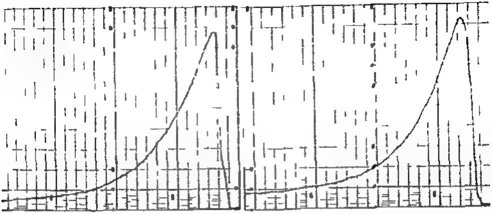


Fig 4 a) Washout curve before catheterization b) When the catheter with OD 3 2 mm is in the position shown in Fig 3

zation 81 and 194 ml/min respectively) not even the greatest catheter (outer diameter 3 2 mm) had any effect on renal blood pressure or mean renal blood flow (Fig 2) No changes in the diameter of the renal artery were observed during the catheterization procedures

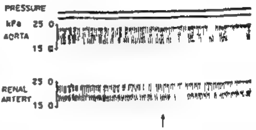
The aortic and renal arterial blood pressure curves the ^{133}Xe washout curve and the aortography in dog No 4 appear in Figs 3 and 4

Discussion

The renal artery was chosen as the most suitable artery to be catheterized because in the resting animal this artery has a high volumetric flow rate as compared with other arteries of the same diameter The catheter induced reduction in blood pressure and mean volumetric flow rate is greater in a vessel with high volumetric flow rate before the catheterization (BJORNO & PETTERSSON 1976 b 1977) Thus in the renal artery catheter induced changes may be more easily detected than in other arteries of the same diameter Also the renal artery supplies an organ without collaterals of importance A collateral supply would seriously disturb the evaluation of the observed hemodynamic effects of catheterization

No decrease in mean blood pressure and mean volumetric flow rate was encountered until catheters were introduced with an outer diameter close to the inner diameter of the artery This was valid in animals in which the diameters of the renal artery the renal blood flow and blood pressure were within expected limits in relation to the weight of the kidney and of the animal These results agree well with the results from the model experiments (BJORNO & PETTERSSON 1977)

a b



c

Fig 3 Aortography and blood pressure curve in dog No 4 a) The catheter with outer diameter 3 2 mm in place in the renal artery b) Aortography with the catheter in the same position c) Aortic and renal arterial blood pressure curves → denotes the moment of catheterization of the renal artery

Results

In dog No 1 (body weight 10 kg kidney weight 25 g diameter of the renal artery 2 4 mm renal blood flow before catheterization 45 ml/min) the smallest catheter had no effect on renal blood pressure (Fig 2) The catheter with outer diameter 2 0 mm induced a moderate decrease of the mean pressure and a very slight decrease of renal blood flow The catheter with outer diameter 2 4 occluded the renal artery After removal of this catheter renal blood flow was not re established because of thrombotic occlusion of the main renal artery and its branches

In dog No 2 (body weight 18 kg kidney weight 40 g diameter of the renal artery 3 1 mm and renal blood flow before catheterization 65 ml/min) the catheter with outer diameter 2 4 had no effect on renal blood pressure while the catheter with outer diameter 2 8 mm induced a slight decrease of the pressure and the catheter with outer diameter 3 2 mm occluded the artery (Fig 2) After removal of this catheter the renal blood pressure and blood flow were re-established

In these two dogs the effect on the systolic pressure was greater than on the diastolic pressure In dog No 2 the percental reduction of the pulse peak pressure was much greater than that of the pulse mean pressure while in dog No 1 the percental reduction of the pulse peak pressure and pulse mean pressure was about the same In dog No 1 the percental decrease of the mean pressure was greater than that of the mean renal blood flow

In the other two dogs Nos 3 and 4 body weight 24 and 37 kg kidney weight 70 and 108 g diameter of renal artery 4 2 and 6 0 mm renal blood flow before catheteri

ZUSAMMENFASSUNG

Bei vier Hunden wurden die hamodynamischen Effekte der Katheterisierung der Nieren arterien analysiert Der Blutdruck der Aorta und der Nierenarterie und die Nierendurch blutung wurden bestimmt und Kontrastmittel vor wahrend und nach der Katheterisierung unter Verwendung von Kathetern mit unterschiedlichen ausseren Diametern injiziert Keine Effekte auf den Blutdruck und die durchschnittliche Nierendurchblutung wurden gefunden solange Katheter verwendet wurden die in ihrem ausseren Diameter dem inneren Diameter der Nierenarterie entsprachen

RESUME

Les auteurs ont étudie sur 4 chiens les effets hemodynamiques du catheterisme de l ar tère renale Ils ont mesure la pression sanguine artérielle renale et aortique et le debit sanguin renal et ont fait des injections de moyen de contraste avant pendant et apres la manoeuvre de cathéterisme en utilisant des catheters ayant des diamètres exterieurs differents Seuls les catheters dont le diamètre exterieur est voisin du diametre interieur de l artère renale ont un effet sur la pression sanguine ou sur le debit sanguin renal moyen

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LINDELL & OLIN (1957), BODIFORSS et coll. (1964) and LÉLEK (1971) observed no catheter induced effects on renal blood flow in the dog. LEITER (1965) recorded a fall in the renal plasma flow in patients during catheterization of the renal artery, but the immediate postcatheterization values (when the catheter was still in position) were virtually the same as in the controls. He regarded these changes as secondary to excitation of nerve endings in the intima of the renal artery during the catheterization maneuver. GARSENSTEIN et coll. (1962) and GÖTHLIN & OLIN (1973) found no reason to assume that the presence of a catheter in the main renal artery altered the blood flow when using catheters of very small diameters compared with the diameter of the renal artery. The present results are in accordance with their statements.

The greater percental decrease in the mean pressure than in the mean renal blood flow, observed in dog No. 1, is in agreement with the model experiments.

In part II it was also demonstrated that in rigid walled vessels the percental reduction of the pulse mean pressure and the percental attenuation of the pulse peak pressure were equal to each other. In elastic walled vessels, however, the attenuation of the pulse peak pressure deviated from that of the pulse mean pressure. This was explained by a geometrical dispersion in a wave guide system (consisting of the liquid core and the elastic vessel wall). Also the wave reflection at the tip of the catheter should be of significance (KANAI et coll. 1970). These observations explain the deviations of the catheter induced reductions of the pulse mean pressure and the pulse peak pressure in dog Nos. 1 and 2.

The physiologic response to a catheter induced lowered pressure and flow rate has not been taken into consideration. This response should be different depending on what organ the artery supplies, collateral supply to the organ etc. and is beyond the scope of this investigation. The experiments reported here, in agreement with the previously reported model experiments, show that catheters with outer diameters close to the inner diameters of the arteries may be used in selective catheterization of the renal artery without significantly decreasing the mean pressure or mean volumetric flow rate distal to the catheter. This is of importance in clinical angiography because these results indicate that there is a rather wide safety margin in most selective angiographic procedures.

SUMMARY

In four dogs the hemodynamic effects of renal artery catheterization has been analysed. Aortic and renal arterial blood pressure and renal blood flow were determined and injection of contrast medium made before, during and after the catheterization maneuver, using catheters with different outer diameters. No effect on the blood pressure or the mean renal blood flow was found until catheters were used with the outer diameter close to the inner diameter of the renal artery.

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ANGIOGRAPHY OF THE TESTICULAR ARTERY

I Method of examination

LARS NORDMARK

Experience in angiography of the testicular artery is limited and reports on testicular angiography seldom appear in the literature In connection with catheterization for selective angiography of other branches of the abdominal aorta it has been found at this department that catheterization of the testicular artery is also possible The localization of cryptorchid testes and the demonstration of testicular agenesis would seem to be important indications for performing angiography of the testicular artery It might also give valuable information when the findings on palpation of the scrotum are uncertain It therefore seemed to be of interest to work out a routine method for selective angiography of this vessel

Historical notes Already in 1955 BRODNY et coll described a selective angiography of the testicular artery performed by puncturing the artery after exposure of the spermatic cord KAHN & FRATES (1968) reported on 11 selective testicular angiographies carried out in connection with other angiographies in patients with normal testicles The examinations were begun with an abdominal aortography For the selective procedure they used a BD RPX 054 catheter 50 cm in length with the end bent into a semi circular curve and with the diameter roughly 30 per cent greater than the inner width of the aorta The rest of the catheter was kept as straight as

Submitted for publication 24 February 1976

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Fig 1 Abdominal aortography Subtraction The testicular artery is seen on both sides (→)

possible The catheter was filled with contrast medium and the injector was retained in position on the catheter during the search for the testicular artery When the vessel had been located the contrast medium was injected irrespective of whether aspiration was possible or not and the catheter was then removed immediately from the orifice of the testicular artery As the method was used for selective arteriography of all the small arteries from the abdominal aorta it is not possible to determine how much of the contrast medium was injected into the testicular artery or how the films were obtained BEN MENACHEM et coll (1974) described the localization of both right and left testicle in a man with bilateral cryptorchidism by means of selective testicular angiography Both testicular arteries were visible on an aortogram and could be catheterized selectively No information regarding the type of catheter used was given Into the right artery 2 5 ml Renografin 60 % was injected and into the left one 5 ml On the left side the testicular artery and the middle suprarenal artery had a common stem and injection of the contrast medium was so painful for the patient that a general anaesthesia had to be given SLORANTA & PIETILÄ in the same year reported on a patient with right renal agenesis in whom in the search for the renal artery the right testicular artery was found instead with three branches to the right suprarenal gland VITALE et coll (1974) localized cryptorchid testes using selective angiography of the spermatic artery in 5 adult males The orifice of the spermatic artery was located under fluoroscopic control with the aid of a J shaped No 5 F polyethylene catheter and 5 to 8 ml of meglumine iothalamate 78 % or meglumine diatrizoate 76 % injected slowly by hand Serial films were taken with a film changer

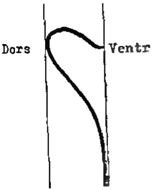

Fig. 2. The selective catheter in the aorta, lateral projection.

Material

Thirty two patients ranging in age from 9 to 71 years, with the average at 34 years, were examined, 7 of them bilaterally and the others unilaterally. The indications were a non palpable testicle in 14, possible tumour in 6, and hydrocele or spermatocele, varicocele, epididymitis, testicular abscess, traumatic haematoma or unexplained testis pain in the others.

Method

All the patients had been prepared as if for an abdominal angiography, in other words they were fasting, their intestines had been irrigated, and they had received premedication with 5 mg of diazepam (Valium, Roche) and 30 mg of pentazocine (Fortalgesic, Winthrop). Boys under 16 were examined under general anaesthesia and men over 20 were given a local anaesthetic.

The arterial puncture was in all cases performed percutaneously in the right groin and a polythene catheter (PE 205) with four side holes was passed up into the aorta with the aid of a guide wire and TV monitoring to the level of L 1. The position was checked with an injection of contrast medium. An abdominal aortography with 2 films/s for 3 seconds was then carried out (Fig. 1). Neither aortic compression nor straining manoeuvres were applied. The films were exposed with an AOT film changer 24 cm × 30 cm and with centering at the level of L 3–4. In the adults 50 ml of diatrizoate 292 mg I/ml (Urografin 60, Schering) were injected with a pressure injector (Cisal II, Siemens Elema) at a pressure of 0.5 MPa (5 kp/cm²) which gave an injection time of 1.8 to 2.0 s. For the boys under 16 the amount of contrast medium was reduced to 40 ml. There were two reasons why the examination was begun with an aortography. First, the search for the testicular artery is considerably facilitated if the vessel is demonstrated in a film obtained by aortography; the selective examination is then confined to a limited area. If the vessel arises from a renal artery it is useless to search for its origin in the aorta. Secondly, it is of importance to have

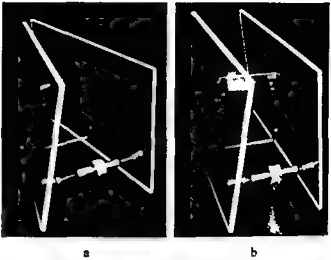

Fig 3 The screw device parting the thighs a) In the folded position b) With the blades opened

information about the width of the aorta in the relevant area so that the catheter for the selective examination is given the correct shape

The selective catheter was then shaped on the basis of the results of the aortography A red No 7 Ödman Ledin catheter tapered at the end and without side holes was used in all the patients It was shaped so that it would turn spontaneously with the tip pointing toward the ventral wall of the aorta This was achieved if the catheter had the appearance illustrated in Fig 2 The bend should be a few millimeters longer than the inner diameter of the aorta in the section of interest If the bend is too long it will glide past the orifice of the testicular artery and such a catheter should be exchanged at once As soon as the selective catheter had reached its position in the aorta contrast medium was injected and the injector was kept on the catheter during the search for the testicular artery When the catheter got caught the position of the tip was checked by a cautious injection of contrast medium If the bend had the correct shape the catheter nearly always remained in position while the arrangements for the exposure of the films were being made With vessels as narrow as the gonadal arteries it is useless to attempt to aspirate when the catheter has become fixed in the orifice of the artery The testicular artery has such a characteristic course that it could usually be identified without difficulty on the TV screen However the narrowest arteries in the agenesis cases were hard to distinguish Similarly a slender vessel running medially over the vertebral bodies could not be seen on the screen

According to earlier anatomic investigations the testicular artery usually arises from the anterior aortic wall between the origins of the renal artery and the inferior mesenteric artery it has been reported as arising from the renal artery in 15 per cent of cases and in a few rare cases from the common iliac artery the inferior phrenic artery or a lumbar artery In the present material of 32 patients it originated from the renal artery in only two instances Superselective injection of contrast medium into a testicular artery originating from the renal artery was not carried out but

Fig 4

Fig 5

Fig 4 Normal testicular artery Subtraction The vessel is slightly dilated due to the contrast injection

Fig 5 Normal testis Magnification angiography Subtraction The head of the epididymis appears as a bulge on the upper pole of the testis

this could probably be achieved in some cases Injection of contrast medium into the renal artery alone gives only limited information The right and left arteries may aris at the same level but more often they arise at different levels It has been stated that 2 or more arteries are present on the same side in 15 to 20 per cent of cases As many as 5 arteries on one side have been mentioned If there are several arteries on one side one of them is usually a main artery When 2 or more arteries exist on the same side injection into the wider vessel has proved to be sufficient if a testis is present but if no testis has been distinguished it has been found useful to try to examine selectively a narrower vessel as well since the width of the different testicular arteries in agenesis cases has depended on which branches have been given off by the respective artery Based on autopsy findings the anatomic variants with respect to number site of origin and arterial course have been described in detail by GÉRARD (1913) NOTKOVICH (1956) and ELISKA (1961) who also gave percentage figures for the different variants

The selective injection of contrast medium was done manually at moderate pressure The injection time was not recorded It varied slightly depending on the width of the artery and was several seconds in a few of the agenesis cases Immediately after the injection the catheter was removed from the vascular orifice in order to reduce the duration of occlusion of the artery to obtain better venous filling and to make sure that the arterial flow was intact after the contrast injection Metrizoate 370 mg I/ml (Isopaque Coronar Nyegaard) was used in the first 8 cases and metrizamide 350 mg I/ml (Amipaque Nyegaard) in the others 1 to 2 ml in cryptorchidism and usually 3 ml when a normal sized testicle was present in the scrotum

The first film was exposed before the injection of the contrast medium to allow

Fig 6

Fig 7

Fig 8

Fig 6 Testis agenesis Subtraction The contrast medium was injected into a testicular artery (→) from which branches run to retroperitoneal tissues Another testicular artery (↔) which ends laterally in a cul-de sac in the pelvis minor has filled through a slender communicating vessel (↔) A lumbar artery has also filled through communicating vessels

Fig. 7 Substraction Cryptorchid testis (→) dorsal to the inguinal canal A few vessels run into the inguinal canal (↔)

Fig 8 Magnification angiography Subtraction Hydrocele (→)

Fig. 9 Epididymitis. Magnification angiography Subtraction The vessels in the dilated epididymis are wide and the circulation is more rapid than in the testis Whereas only arteries are present in the testis only veins are visible in the epididymis (→)

Fig 9

subtraction In the arterial phase one frame was exposed per second and in the venous phase one frame per 6 seconds the last one 26 s after the start of the contrast injection In the patients with cryptorchidism views were taken first over the cranial part of the vascular area and then when necessary over the small pelvis the inguinal canal and the scrotum If the indication for the examination had been possible

abnormality of a testis located in the scrotum only geometric magnification angiography of the testis was performed using a microfocus tube (0 1 mm × 0 1 mm) The focus-object distance was reduced to a minimum and the degree of magnification was thus 2 to 2½ times To reduce the radiation dose the thighs were pushed apart with the aid of a screw device (Fig 3) and the testis was placed on a foam rubber cushion positioned between the legs The roentgen tube was tilted so that the angle of projection from the cranial aspect was 30 As a result of this arrangement the gonad dose could be kept as low as 0 5 to 0 75 mGy (50 to 75 mrad) per exposure The camera speed could be reduced to one frame every two seconds in the arterial phase without any loss of information Subtraction was used in all cases which in some instances increased the diagnostic certainty

In 5 patients, the testicular artery could not be injected selectively In 2 of these it arose from the renal artery In a man of 51 years with probable bilateral agenesis no testicular artery could be identified either on the right or the left side In a man 71 years old with a tortuous aorta and moderate atherosclerosis catheterization proved impossible and in one case catheterization was not successful due to a subintimal injection of the contrast medium

Complications during or after the angiography occurred in 2 instances One of these was connected with the above mentioned subintimal injection the patient experiencing moderate pain in the back which gradually subsided over a period of 10 minutes He was completely free from discomfort when he left the department The other case was that of a moderately severe haematoma in the groin

A normal testicular artery with its narrow side branches appears in Fig 4 and a normal testicle with the epididymis in Fig 5 Fig 6 is an example of testicular agenesis Fig 7 demonstrates a cryptorchid testis and Figs 8 and 9 hydrocele and epididymitis respectively

Discussion

Testicular angiography is of value for preoperative localization of a non palpable testicle and for establishing the existence of agenesis Both of these factors are important as malignant tumour in a cryptorchid testis is approximately 30 times more common than if the testis is located in the scrotum Patients with agenesis can be spared extensive and sometimes heroic operations The indications for testicular angiography in a patient with a palpable testis are not yet clearly defined In principle the examination is not more difficult to perform than other selective angiographies and it usually causes no greater discomfort than these It is however essential that the technical equipment should be of good quality The equipment required is described and attention is drawn to special problems likely to arise during the examination The results of testicular angiography carried out on different indications are to be reported in later communications

SUMMARY

A method for selective testicular angiography is presented The indications are discussed and a few typical examples of the angiographic appearances are illustrated

ZUSAMMENFASSUNG

Eine Methode fur die selektive Angiographie der A testicularis wird beschrieben Die Indikationen werden diskutiert und einige typische angiographische Bilder werden vorgelegt

RÉSUMÉ

Présentation d une méthode sélective pour l angiographie testiculaire L auteur discute ses indications et donne quelques exemples typiques des aspects angiographiques

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METRIZAMIDE IN ANGIOGRAPHY

I Femoral angiography

T ALMEN E BOIJSEN and S E LINDELL

In angiography ionic water soluble contrast media have been used with an osmolality of 1 5 to 2 5 osm while the osmolality of human serum is 0 3 osm The injection of these media into the femoral artery is often painful and is followed by an increased blood flow ascribed to vasodilatation From results gained in experiments on dogs (HILAL 1966) and cats (LINDGREN et coll 1967 1968) it has been concluded that this vasodilatation to some extent is caused by the hypertonicity relative to plasma of the contrast medium

In order to reduce the hypertonicity of water soluble contrast media non ionic water soluble media were proposed (ALMEN 1969) and synthesized (HOLTERMANN 1973) It has been suggested (ALMEN & TRAGARDH 1973) that femoral angiography with non ionic contrast media might cause less pain on account of their reduced osmolality

The present investigation was intended to find out whether a non ionic contrast medium (metrizamide) produced less pain and less change in blood flow than an ionic medium (metrizoate) when injected into the femoral artery in man and if so less pain was produced also when metrizamide was injected into the brachial external carotid or internal iliac arteries

Supported in part by the Swedish Medical Research Council (Project No 3483) Submitted for publication 12 May 1976

Material and Methods

In 20 patients referred for angiography which required more than one injection of contrast medium one of the the injections was made with Amipaque (metrizamide 280 mg I/ml) while the other injections were made with an equal volume of Isopaque Cerebral (meglumine/calcium metrizoate 280 mg I/ml) In each patient the rate of injection of the two contrast media was the same In 14 patients Isopaque Cerebral was injected both before and after Amipaque while in the remaining 6 patients Amipaque was injected at the end of the examination

The amount of contrast medium was 30 ml per injection into the distal abdominal aorta in 16 patients (bilateral femoral angiography) 10 ml per injection into the two internal iliac arteries in 2 patients (bilateral simultaneous injection) 10 ml per injection in one patient (brachial angiography) and 6 ml per injection in one patient (external carotid angiography)

The age of the 20 patients ranged from 37 to 78 years and the weight from 46 to 80 kg Twelve of the patients were females The patients were observed after each injection concerning signs of pain and were asked about the degree of discomfort caused by the injection When the examination was finished each patient was asked which injection had caused the least discomfort

In 15 legs the blood flow in the calves was measured with strain gauge plethysmography using electrical calibration (HALLBÖÖK et coll 1970) The patients were supine with the calves just below the level of the heart The strain gauge was placed around the largest part of the calf about 15 cm distally to the knee with the occlusive cuff immediately proximal to the knee The blood flow was recorded on a Mingograf about every 10 seconds and curves were obtained before and after each injection of contrast medium The interval between the injection and the first blood flow recording after the injection was 15 to 30 seconds The mean value of the last 2 or 3 measurements preceding the injection was considered as the preinjection value The flow after the injection was calculated from the mean of the 2 highest consecutive recordings after the injection In view of the tendency for the change in blood flow to decrease with increasing number of injections the effect of Amipaque was in all but 2 legs compared with the effect of Isopaque Cerebral given 15 min after the injection of Amipaque In the remaining 2 legs the effect on blood flow of Amipaque was compared with the effect of the injection of Isopaque Cerebral 15 min before the Amipaque injection

Results

Pain reaction After the angiography all 20 patients declared that one of the injections had caused less discomfort than the other and in all this was identified as the Amipaque injection None of the 20 patients considered the Amipaque injection as painful while in 15 the injection of Isopaque Cerebral was painful (Table I) In 7 patients the difference between Amipaque and Isopaque Cerebral was obvious

Table 1

Discomfort during injection of Amipaque and Isopaque Cerebral

Reaction	Amipaque	Isopaque Cerebral
Obvious pain*	0	7
Pain**	0	8
Strong feeling of heat	6	4
Slight feeling of heat	13	1
No sensation	1	0

* The patients complained loudly

** The patients were calm and silent but on questioning declared that the injection was followed by pain

without questioning because they complained loudly of pain following all the injections of Isopaque Cerebral both those preceding and those following the Amipaque injection They showed no obvious signs of pain following the Amipaque injection

The 5 patients in which the injections of Isopaque Cerebral had not been painful indicated that they had experienced more heat following injection of Isopaque Cerebral than of Amipaque (Table 1)

The injection of Isopaque Cerebral was considered as painful by the 4 patients in which the contrast medium was injected into the external carotid brachial or internal iliac arteries 2 of these complained of pain during the injection of Isopaque Cerebral none experienced any pain following the injection of Amipaque

Blood flow in the calves All measurements of blood flow demonstrated an increase following injections of both Isopaque Cerebral (Table 2) and Amipaque (Table 3) following Isopaque Cerebral about 95 per cent and following Amipaque about 25 per cent This difference is significant ($p < 0$ 001 paired t test)

Diagnostic information The two contrast media were injected at the same rate in equal volumes and with the same iodine concentration (280 mg I/ml) In the films the arteries had the same diameter and the same number of small peripheral branches was demonstrated (Figure)

Discussion

Following intra arterial injection of Amipaque all the present patients experienced less pain and less discomfort than following injection of Isopaque Cerebral This advantageous property of the Amipaque solution seems to be related to the fact that it is less hypertonic in relation to human serum than the solution of Isopaque Cerebral the osmolality of Amipaque (280 mg I/ml) is 0 46 mol/kg water while that of Isopaque Cerebral (280 mg I/ml) is 1 46 and that of human serum is 0 30 The concept that the pain following injection of water soluble contrast media into an artery is

Table 2

Blood flow in lower leg before and after injection of Isopaque Cerebral. Flow expressed as ml blood per 100 ml tissue per minute. n = number of legs. $\bar{x}$ = mean value of blood flow. $\bar{d}$ = mean difference before and after injection. Paired t test

Before	After	Difference
n = 15	n = 15	n = 15
$\bar{x}$ = 2.09	$\bar{x}$ = 4.07	$\bar{d}$ = 1.98
SD 0.76	SD = 1.09	SD_d = 1.29
SE 0.[illegible]0	SE = 0.28	SE_d = 0.33
p 0.001		

Table 3

Blood flow in lower leg before and after injection of Amipaque. Flow expressed as ml blood per 100 ml tissue per minute. n = number of legs. $\bar{x}$ = mean value of blood flow. $\bar{d}$ = mean difference of blood flow before and after injection. Paired t test

Before	After	Difference
n = 15	n = 15	n = 15
$\bar{x}$ = 1.93	$\bar{x}$ = 2.43	$\bar{d}$ = 0.49
SD 0.89	SD = 0.74	SD_d = 0.59
SE 0.23	SE = 0.19	SE_d = 0.15
p 0.01		

partly caused by the hypertonicity of the media is in agreement with previous observations of contrast media with reduced osmolality. Emulsions, suspensions and polymers of contrast media have been tried in order to reduce the osmotic effect. SAITO et coll. (1930) used an emulsion of iodinized oil for femoral and carotid angiography in 130 patients. They found that it did not produce any pain. The previously used suspension of thorium dioxide was also characterized by absence of pain. BJÖRK et coll. (1969) found that the use of a dimer of metrizoate for femoral angiography was accompanied by reduced pain, and this finding could partly be ascribed to the osmolality of the dimer which was lower than that of the other substances examined.

In the present investigation injection of low osmotic Amipaque into the aorta produced less increase in the blood flow through the lower leg than injection of high osmotic Isopaque Cerebral. This finding is in agreement with a previous report by ALMÉN & TRAGÅRDH (1973). Different contrast media were injected into the femoral artery of anaesthetized dogs and two non ionic contrast media produced less changes in blood flow through the femoral artery than two ionic monomeric media (diatrizoate and iothalamate) and one dimeric ionic medium (iocarmate). The higher the osmolality of the contrast medium solution, the higher the increase in femoral blood flow.

a) Film of lower leg following injection of 30 ml Isopaque Cerebral (280 mg I/ml) into abdominal aorta A few seconds later the patient moved his leg and complained loudly of pain b) *Same examination as in (a) Injection of 30* ml Amipaque (?80 mg I/ml) The patient experienced no pain The details are similar in (a) and (b)

BOIJSEN et coll (1971) used Isopaque Cerebral in femoral angiography with a technique similar to the present one Following the injection they observed an initial decrease in blood flow through the lower leg which reached its minimum about 10 to 15 seconds *after the beginning of the injection In the present investigation this* initial decrease was not recorded because post injection measurement of blood flow was *not* resumed until 15 to 30 seconds after the beginning of the injection

Conclusion In order to reduce the pain caused by contrast medium during angiography non ionic water soluble media should be developed for routine clinical use

SUMMARY

In 20 patients the non ionic Amipaque (metrizamide) and the ionic Isopaque Cerebral (meglumine/calcium metrizoate) were injected into the femoral brachial internal iliac or external carotid arteries Strain gauge plethysmography of the lower leg demonstrated less increase in blood flow following injections of Amipaque (25°) than following injections of Isopaque Cerebral (95) None of the 20 patients complained of pain following injection of Amipaque 15 experienced pain following Isopaque Cerebral

Table 2

Blood flow in lower leg before and after injection of Isopaque Cerebral. Flow expressed as ml blood per 100 ml tissue per minute. n = number of legs. $\bar{X}$ = mean value of blood flow. $\bar{d}$ = mean difference before and after injection. Paired t test

Before	After	Difference
n 15	n 15	n = 15
$\bar{X}$ 2.07	$\bar{X}$ 4.07	$\bar{d}$ = 1.98
SD 0.76	SD 1.09	SD_d = 1.29
SE 0.20	SE = 0.28	SE_d = 0.33
p 0.001		

Table 3

Blood flow in lower leg before and after injection of Amipaque. Flow expressed as ml blood per 100 ml tissue per minute. n = number of legs. $\bar{X}$ = mean value of blood flow. $\bar{d}$ = mean difference of blood flow before and after injection. Paired t test

Before	After	Difference
n = 15	n = 15	n = 15
$\bar{X}$ 1.93	$\bar{X}$ = 2.43	$\bar{d}$ = 0.49
SD 0.88	SD = 0.74	SD_d = 0.59
SE 0.23	SE 0.19	SE_d = 0.15
p 0.01		

partly caused by the hypertonicity of the media is in agreement with previous observations of contrast media with reduced osmolality. Emulsions, suspensions and polymers of contrast media have been tried in order to reduce the osmotic effect. SAITO et coll. (1930) used an emulsion of iodinized oil for femoral and carotid angiography in 130 patients. They found that it did not produce any pain. The previously used suspension of thorium dioxide was also characterized by absence of pain. BJÖRK et coll. (1969) found that the use of a dimer of metrizoate for femoral angiography was accompanied by reduced pain and this finding could partly be ascribed to the osmolality of the dimer which was lower than that of the other substances examined.

In the present investigation injection of low-osmotic Amipaque into the aorta produced less increase in the blood flow through the lower leg than injection of high-osmotic Isopaque Cerebral. This finding is in agreement with a previous report by ALMÉN & TRAGARDH (1973). Different contrast media were injected into the femoral artery of anaesthetized dogs and two non ionic contrast media produced less changes in blood flow through the femoral artery than two ionic monomeric media (diatrizoate and iothalamate) and one dimeric ionic medium (iocarmate): the higher the osmolality of the contrast medium solution, the higher the increase in femoral blood flow.

a) Film of lower leg following injection of 30 ml Isopaque Cerebral (280 mg I/ml) into abdominal aorta A few seconds later the patient moved his leg and complained loudly of pain b) Same examination as in (a) Injection of 30 ml Amipaque (280 mg I/ml) The patient experienced no pain. The details are similar in (a) and (b)

BOUSEN et coll (1971) used Isopaque Cerebral in femoral angiography with a technique similar to the present one Following the injection they observed an initial decrease in blood flow through the lower leg which reached its minimum about 10 to 15 seconds after the beginning of the injection In the present investigation this initial decrease was not recorded because post injection measurement of blood flow was not resumed until 15 to 30 seconds after the beginning of the injection

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SUMMARY

In 20 patients the non ionic Amipaque (metrizamide) and the ionic Isopaque Cerebral (meglumine/calcium metrizoate) were injected into the femoral brachial internal iliac or external carotid arteries Strain gauge plethysmography of the lower leg demonstrated less increase in blood flow following injections of Amipaque (25 %) than following injections of Isopaque Cerebral (95) None of the 20 patients complained of pain following injection of Amipaque 15 experienced pain following Isopaque Cerebral

ZUSAMMENFASSUNG

In 20 Patienten wurde das nicht ionisierte Kontrastmittel Amipaque (Metrizamid) und das ionisierte Kontrastmittel Isopaque Cerebral (Meglumin/Kalzium Metrizoat) in die Arteria femoralis, brachialis, iliaca interna oder carotis externa injiziert. Plethysmographie des Unterschenkels zeigte, dass die Blutdurchströmung weniger erhöht war nach Injektion von Amipaque (25%) als nach Injektion von Isopaque Cerebral (95%). Schmerz wurde von keinem der 20 Patienten nach Injektion von Amipaque empfunden, dagegen aber von 15 nach Injektion von Isopaque Cerebral.

RÉSUMÉ

Vingt malades ont subi une injection dans les artères fémorales, humérales, iliaques internes ou carotides externes d'Amipaque (métrizamide) et d'Isopaque Cérébral ionique (métrizoate de méglumine calcium). La pléthysmographie par jauge électrique du membre inférieur a montré une moindre augmentation du débit sanguin après injection d'Amipaque (25%) qu'après injection d'Isopaque Cérébral (95%). Aucun des vingt malades ne s'est plaint de douleurs après injection d'Amipaque. 15 avaient souffert après injection d'Isopaque Cérébral.

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EFFECT OF ANGIOTENSIN ON NORMAL RENAL CIRCULATION DETERMINED BY ANGIOGRAPHY AND A DYE DILUTION TECHNIQUE

L EKELUND and J GOTHLIN

Vasoconstrictors have been used for more than one decade in order to improve the information at angiography of renal tumours Intravenous infusion or arterial and venous bolus injections have been applied However no interest has been paid to the suitable interval between drug administration and angiography The response to vasoactive drugs at varying intervals after the drug administration has only been discussed in one report on vasopressin (GOTHLIN 1976) With this model in mind angiotensin which for some years has been routinely used at this department has been tested in normal kidneys

Material and Methods The material comprised two groups each consisting of 6 patients referred for angiography because of possible renal tumour but where no malignant lesion could be demonstrated In one group films were obtained before and 10 s 2 5 and 15 min after rapid intraarterial injection of 0 5 or 1 0 μg angiotensin (Hypertensin N Ciba Switzerland) In the other group renal blood flow (RBF) appearance time of dye (AT) in the renal vein and mean transit time (MTT) of the dye was determined before and 5 to 10 s 2 5 10 15 and 20 min after arterial bolus injection of 0 5 and 1 0 μg angiotensin Due to the technique some aberrations from the time schedule could occur and in most cases more frequent examinations were made (For details of the angiographic and dye dilution techniques see GÖTHLIN 1976 and GOTHLIN & OLIN 1973)

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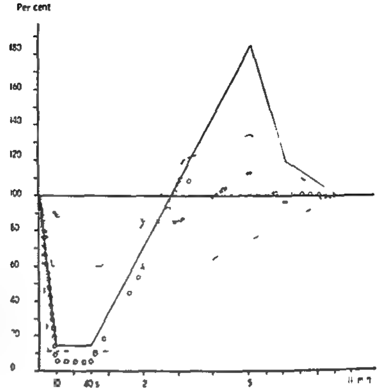

Fig. 1. Renal blood flow after administration of 0.5 μg (——) or 1.0 μg (……) angiotensin (in per cent of preinjection value). The stippled area indicates such a low flow that it could not be calculated.

Results

After administration of 0.5 or 1.0 μg angiotensin the renal blood flow initially decreased to values too low to enable calculation (Fig. 1). This depression lasted about 2 min and was followed by increased flow to 110 to 180 per cent of control. All flow values had returned to preinjection value within 10 min. In one patient receiving 1 μg angiotensin no increase in flow above preinjection value was recorded.

The appearance time increased with 5 to 6 s initially after angiotensin (Fig. 2). After 2 min there was a decrease of 0.2 to 2.9 s compared with control except in one patient with a slight increase during 20 min. The decrease in appearance time was in two patients followed by a slight increase. After 20 min the AT was close to control values.

Immediately after the angiotensin the mean transit time increased to values impossible to calculate (Fig. 3). After 2 to 3 min the MTT decreased below control with 0.5 to 2 s in 4 patients and approached control in two of them. After 20 min MTT was close to normal in all patients.

The changes in RBF, AT and MTT were reflected at angiography by initial spill back of contrast medium into the aorta, prolonged emptying time of the arteries and the arcuate and interlobular arteries were not discernible (Fig. 4). The nephrographic phase was delayed and poor. The appearance time of contrast medium in intrarenal

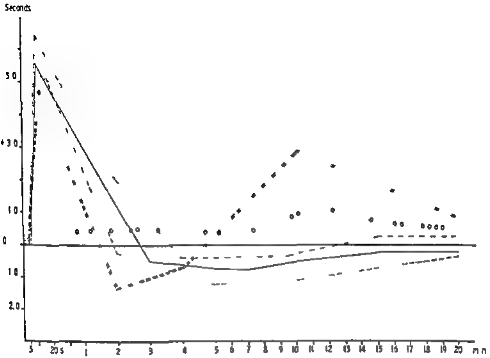

Fig 2 Appearance time of dye in the renal vein after administration of 0 5 μg (—— ---) or 1 0 μg (== -- OO) angiotensin calculated in s above or below control

and renal veins was increased and the concentration of medium decreased (Fig 5 b)

Two min after administration of angiotensin no spill back of contrast medium occurred the emptying time of the arteries was normal the arcuate arteries were visible (Fig 4 c) the nephrographic phase somewhat improved and appearing earlier the kidney size somewhat decreased and the appearance time and the concentration of contrast medium in the veins normalized (Fig 5 c)

When the RBF increased above control with concomitant decrease of AT and MTT the emptying time of the arteries was somewhat decreased (Fig 4 d) the nephrographic phase more intense and appeared slightly earlier than in control the kidney size normalized the appearance time of contrast medium in the veins somewhat decreased and the concentration of medium normal (Fig 5 d)

Fifteen min after the drug administration the angiography was again normal

The nephrographic phase was much delayed 10 s after angiotensin and appeared somewhat earlier 5 min after drug administration The decrease in nephrographic phase was homogeneous

The following parameters were unchanged at all angiographies after angiotensin width length tortuosity concentration of contrast medium in and number of ar

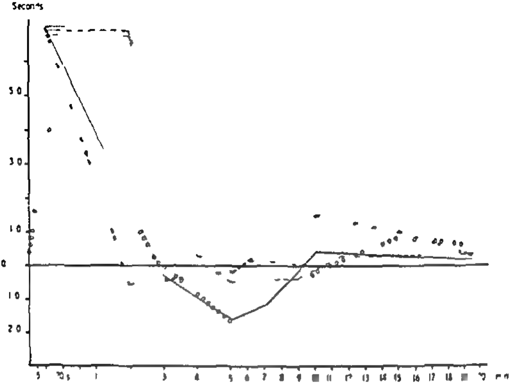

Fig. 3. Mean transit time of dye after administration of 0.5 μg (—— ---) or 1.0 μg (— —) angiotensin, calculated in s above or below control.

teries demonstrated. The information of arterial details was never improved. The width of the veins never changed.

Discussion

By using repeated serial angiography and a dye dilution technique for determination of renal blood flow, appearance time and mean transit time of the dye a model for testing the influence of vasoactive drugs on renal circulation has been obtained. Previously it was used for an analysis of the effect of vasopressin (GÖTHLIN 1976). Angiotensin, which empirically has been used to improve the information at nephroangiography, was the second drug of choice and it is intended to investigate other vasoactive agents by this model. It should thus be possible to establish a ground for using different drugs and to find a suitable dose and interval between drug administration and angiography.

The angiotensin was administered intraarterially in order to have a fast and localized action of the drug.

FINBERG & PEART (1972), using three moderate doses of angiotensin in rats, established a linear relationship between the response in kidney volume and the log

c d

Fig. 4. Early arterial phase. a) Before injection. b) 10 s after angiotensin. Reflux of contrast medium into the aorta and no filling of peripheral arteries indicating increased peripheral resistance. c) 2 min later: return to preinjection condition. d) 5 min after angiotensin. Increased flow indicated by the fact that no contrast medium is present in the proximal part of the renal artery

arithmic dose of the drug. Changes in kidney volume may result from alterations in either intravascular or intratubular volume. The vascular volume (VV) can be calculated from the RBF and the MTT according to the formula VV (in ml) = RBF (in ml/s) × MTT (in s).

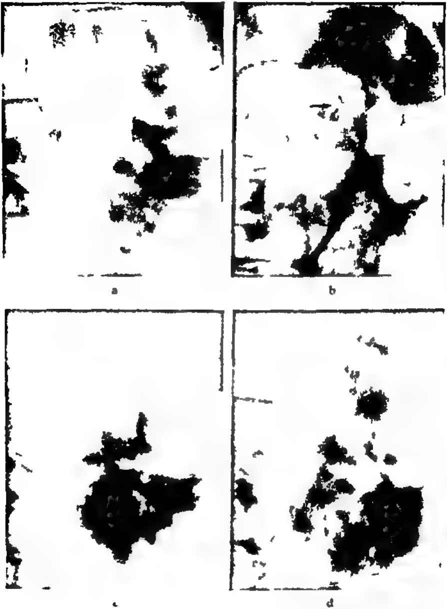

Fig. 5. 3 s after injection of contrast medium. a) Control. The renal veins well demonstrated. b) 10 s after angiotensin. Contrast medium in intrarenal arteries (→). Poor nephrographic phase. No intra- or extrarenal veins visible. c) 2 min later. The renal veins well demonstrated and the nephrographic phase improved. d) 5 min after angiotensin. The renal veins appear earlier and the maximum concentration of contrast medium appears earlier. Nephrographic phase further improved.

Table

Angiographic changes following administration of 0.5 to 1.0 μg angiotensin in the renal artery

	Time after administration			
	10 s	2 min	5 min	15 min
Emptying time of renal arteries (s)	−3 5	0	−0 5	0
Intensity of nephrographic phase	− − −	− −	−	0
Kidney size (mm)	0	−4 2	0	0
Appearance time (s)	+4	0	−0 5	0
Contrast concentration in renal veins	− −	0	0	0

In the present series the RBF decreased to such a level (Fig 1) that this evidently alon may explain the decrease in kidney size (Table) as being due to decreased vascular volume However afferent arteriolar constriction can cause a marked reduction in proximal tubular volume and collapse of proximal tubulus has been observed in the rat by FINBERG & PEART The reduction in kidney size may thus be due to a combination of reduced vascular and tubular volume

The reduction in vascular volume lies probably on the arterial side as angiotensin in general is a much weaker constrictor of veins than of arteries (HADDY et coll 1962 ROSE et coll 1962)

Angiotensin has been used at nephroangiography in man by EKELUND et coll (1972) In no case did any dose of angiotensin immediately before angiography change the caliber of the main renal or interlobar arteries and contrast medium rarely filled more peripheral arteries The arterial emptying time increased and the nephrographic phase was delayed and poor These findings have also been reported by MICHEL & MOREAU (1973) and were encountered also in the present series They occurred when the depression of RBF was most marked and the AT and MTT increased However the site of action cannot be demonstrated with the present technique

Species differences in the angiographic response to angiotensin exist Following intraarterial administration of 0 1 μg angiotensin in rabbit there is an initial decrease in renal artery width and an increase in the concentration of contrast medium within the arteries (GÖTHLIN 1975)

The emptying time of the arteries was initially unchanged but increased at 30 s and was much increased 50 s after drug administration ELKIN & MENG (1966) in dogs reported dilatation of the main renal and interlobar arteries after 0 5 to 45 μg angiotensin NERI et coll (1961) in dogs at angiography after 0 5 to 1 0 μg angiotensin per kg bodyweight observed a dilatation of the first renal arterial branches and the aorta together with an apparent constriction of the smaller arterial branches and a marked delay of the nephrographic phase

The initial increase in AT (Fig. 2) and MTT (Fig. 3) in the present cases reflects an increased vascular resistance. It is also indicated at angiography by spill back of contrast medium into the aorta. The increased AT and MTT have been observed in the rabbit with angiography and dye dilution technique (GÖTHLIN, unpublished data) and delayed AT at angiography in dog has been reported by ELKIN & MENG. In animals FINNERTY (1962), PETERS (1963) and GROSS et coll. (1964) state that the increased vascular resistance is mainly induced by efferent arteriolar constriction. NERI et coll. concluded from angiography in dogs that the increased vascular resistance was due to constriction of the glomerular vessels.

Reduction in RBF in man caused by angiotensin has been reported by several authors (BOCK & KRIECKE 1958, FINNERTY, LARAGH et coll. 1963) and in animals by AUKLAND (1968), GRANGSJÖ & PERSSON (1968) and CARRIÈRE & FRIBORG (1969). The mechanism behind the reduction of the RBF is not quite clear. Most likely species difference in the site of action exists. In man the most marked increased vascular resistance is reported to occur in vas afferens (BOCK & KRIECKE) or the efferent arteriole of the juxtamedullary glomeruli or more likely on the vasa recta themselves (CARRIÈRE & FRIBORG).

The increase in RBF (Fig. 1) with the concomitant decrease in AT and MTT is most likely a form of reactive hyperemia subsequent to the ischemia. The same response regarding RBF has been demonstrated after vasopressin in human kidneys by GÖTHLIN and in the human liver by BARR et coll. (1975).

The AT followed the RBF closely after angiotensin administration while an early appearance time of contrast medium was found in the renal vein after vasopressin administration in human kidneys favouring the theory that vasopressin induces juxtamedullary shunting in the kidneys (GÖTHLIN). There is no evidence of shunting after angiotensin.

The second increase in AT (Fig. 2) about 10 min after angiotensin when the RBF is already normal, has not been explained. The MTT (Fig. 3) is not quite normalized either and perhaps is the action of the drug more longlasting than 10 min despite the normalized RBF and normalized angiography.

The increased accuracy of the diagnosis of malignant renal lesions after angiotensin is probably mainly due to suppression of the normal vasculature while the neoplastic vessels with absence of contractile elements are less or not at all influenced by the drug.

An interval of 10 to 60 s between the intraarterial angiotensin injection and the angiography and the dose of 0.5 to 1.0 μg applied in malignant kidney lesions is to be preferred as it suppresses the normal renal circulation enough to be of diagnostic value but the effect is not unnecessary longlasting.

The present investigation supports the recommendation given in a previous report by EKELUND et coll. (1972): (1) the angiography should be performed 10 to 60 s after administration of angiotensin and (2) the optimum dose is 0.5 to 1.0 μg angiotensin in renal tumours.

SUMMARY

Angiotensin in a dose of 0.5 to 1.0 μg injected into the renal artery of healthy kidneys initially decreased renal blood flow and increased the appearance time and mean transit time of dye and contrast medium as examined by a dye dilution technique and angiography. The initial phase is followed by a reactive hyperemia. The increased vascular resistance is probably localized peripherally on the arterial side of the vascular tree. Optimum dose is 0.5 to 1.0 μg angiotensin in diagnosis of renal tumours. Optimum interval between drug administration and angiography is 10 to 60 s.

ZUSAMMENFASSUNG

Angiotensin in einer Dosis von 0.5 bis 1.0 μg, das in die Nierenarterie von gesunden Nieren injiziert wurde, vermindert initial die Nierendurchblutung und verlängert die Erscheinungs-zeit und mittlere Durchströmungszeit von Farbstoff und Kontrastmittel, wie durch die Farbstoff-Verdünnungstechnik und Angiographie festgestellt worden war. Der Initialphase folgt eine reaktive Hyperämie. Der gesteigerte Gefässwiderstand ist wahrscheinlich peripher in den Ästen der Nierenarterie lokalisiert. Optimale Dosen sind 0.5 bis 1.0 μg Angiotensin für die Diagnose von Nierentumoren. Das optimale Intervall zwischen der Angiotensingabe und der Angiographie ist 10 bis 60 Sekunden.

RESUME

L'injection de 0.5 à 1.0 μg d'angiotensine dans l'artère rénale d'un rein sain diminue d'abord le débit sanguin rénal et augmente le délai d'apparition et la durée moyenne de transit des marqueurs et des moyens de contraste etudiés par la technique de dilution de marqueur et par l'angiographie. La phase initiale est suivie d'une hyperhémie réactionnelle. L'augmentation de la résistance vasculaire est probablement localisée à la périphérie du versant artériel de l'arbre vasculaire. L'optimum de dose d'angiotensine pour le diagnostic des tumeurs rénales est de 0.5 à 1.0 μg. L'intervalle optimum entre l'administration de cet agent et l'angiographie est de 10 à 60 secondes.

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SELECTIVE ARTERIAL EMBOLISATION IN THE MANAGEMENT OF POST OPERATIVE RENAL HAEMORRHAGE

M LEA THOMAS and G H R LAMB

Selective arterial embolisation has been used at a number of different sites for the control of haemorrhage Pelvic haemorrhage following trauma has been controlled by embolisation of branches of the iliac arteries (RING et coll 1973) and intractable epistaxis by embolisation of the maxillary artery (SOKOLOFF et coll 1974) Gastric bleeding has been controlled by embolisation of the left gastric artery (GOLDSTEIN et coll 1975) and renal arterial embolisation has been employed to control haemorrhage following trauma (CHUANG et coll 1975)

The use of selective renal arterial embolisation to control severe secondary haemorrhage following partial nephrectomy is now described

Case report

A man aged 39 was found to be hypertensive at routine insurance medical examination Urography retrograde pyelography and nephroangiography demonstrated a cyst at the lower pole of the right kidney but no other abnormality on either side

As it was thought that the renal cyst might be the cause of the hypertension surgical removal was recommended At operation a multilocular cyst was found at the lower pole of the right kidney and a partial nephrectomy performed No complications occurred at

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Fig. 1. Urography at time of first attack of haematuria. Tomography. Dilatation of the right upper pole calyx. Blood clot in the pelvis and right ureter. The left kidney and ureter appear normal.

Fig. 2. Urography 3 months after right renal artery embolisation. Tomography. Slight reduction in the size of the right renal remnant since the pre-embolisation examination. Lower pole heminephrectomy.

Fig 3

Fig 4

Fig 3 Pre-embolisation right nephroangiography A lower pole artery is ligated (→) Arterial branches in the lower pole

Fig 4 Repeat right nephroangiography immediately following embolisation Some of the arterial branches to the lower pole are occluded A little blood clot is present in the upper pole arteries

the time of the operation or in the immediate post operative period The patient was discharged 10 days later

Three weeks after the operation the patient developed haematuria and clot retention and had to be readmitted At urography there was a hydronephrosis on the right side indicating obstructive uropathy The renal pelvis right ureter and much of the bladder were filled with blod clot The left kidney remained normal (Fig 1) The haematuria stopped without treatment in 5 days Ten days later the haematuria recurred and despite blood transfusions the patient s haemoglobin continued to fall reaching 88 g/l At repeat urography the right kidney was non functioning The patient s condition made further major surgery inadvisable and it was felt that the remainder of the right kidney should be preserved if at all possible For these reasons selective transcatheter embolisation was performed Following this the haematuria ceased and there has been no recurrence

Three months later a repeat urography (Fig 2) demonstrated prompt and equal excretion of contrast medium on both sides The right kidney remnant was a little smaller than previously The patient s blood pressure has remained stable on medical treatment

Technique Ten ml of the patient s venous blood were allowed to coagulate in a sterile container A bilateral flood nephroangiography was carried out using a percutaneous femoral technique to confirm the normality of the left kidney and to show the position and number of the right renal arteries

A preformed 8 FR (2 7 mm) femoro-renal catheter (Ducor Cordis Corporation Miami USA) was introduced into the right renal artery Eight ml of meglumine iothalamate 60% was injected by hand and a series of films taken of the right kidney with an AOT film changer (Fig 3)

The examination demonstrated the site of ligation of the lower polar artery but no other abnormality In particular there was no evidence of a bleeding site on either the early or delayed films

The catheter was then advanced under television screening further into the renal artery towards the lower pole branches and a test injection made to confirm the position of the catheter tip

About 1 5 ml of the patient s coagulated blood mixed with 8 ml of meglumine iothalamate 60° was then injected under television control The mixture was seen to pass largely into the lower pole arteries A repeat angiography was immediately performed to demonstrate the distribution of the blood clot in the renal arterial branches Blood clot was found mainly in the lower pole arteries but a little also in the upper pole branches (Fig 4)

Discussion

Ideally the emboli should be injected selectively into the arteries from which the bleeding is occurring

The shape of the catheter used at this examination prevented it being advanced to the optimum position that is close to the branches to the lower pole As a result a little blood clot passed into the upper pole branches

It has been shown in dogs (CHUANG et coll 1975) that injection of autogenous blood clot into a main renal artery does not produce massive infarction although the renal size decreased about 10 per cent and microscopically small infarcts were seen On the repeat urography although there was no loss of renal substance at the upper pole the kidney remnant was slightly smaller than before embolisation raising the possibility of small areas of infarction

In the animal experiments of CHUANG et coll no dog developed hypertension and in the present case the blood pressure did not increase either immediately after embolisation or on follow up The absence of significant infarction may be due to the fact that autogenous blood clot is lysed in a few hours

It has been stated that at least 0 5 ml per minute of arterial haemorrhage is required for its angiographic demonstration (NUSBAUM & BAUM 1963) This is presumably why no bleeding point was found at angiography in the present case

In the control of haemorrhage various substances other than autogenous blood clot have been employed These include lead shot (RIZK et coll 1973) and Gelfoam particles (SOKOLOFF et coll 1974) It has also been suggested that the addition of Amicar to autogenous blood clot may prolong the duration of arterial occlusion and thus be more effective (CHUANG et coll 1975)

However autogenous blood clot seems likely to be the safest material available at the present time

The present case report draws attention to the value of a relatively simple technique of percutaneous catheter embolisation in the treatment of renal haemorrhage Although the procedure has been used following renal biopsy and trauma no case of its use in secondary surgical haemorrhage has been reported

SUMMARY

A case is reported in which selective renal artery embolisation using autogenous blood clot was effective in the control of persistent haematuria following partial nephrectomy

ZUSAMMENFASSUNG

Selektive Embolisierung der Arteria renalis unter Verwendung eines autogenen Blutkoagels erwies sich in einem Fall effektiv um eine bestehende Hämaturie nach partieller Nephrektomie zu kontrollieren

RESUME

Présentation d un cas où l embolisation sélective de l artère renale utilisant un caillot sanguin autogene a ete efficace pour le traitement d une hematurie persistante apres nephrectomie partielle

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Book review

MAGNIFICATION RADIOGRAPHY. By S. Takahashi and S. Sakuma. 110 pages with 59 figures. Springer-Verlag, Berlin-Heidelberg-New York 1975. Price DM 78.—

Magnification radiography is a collection and presentation of the major research work on this subject, which is of great value because of the growing interest in magnification during recent years. The book gives an excellent survey of the magnification method, especially from the physical and technical standpoints. Although the English translation could be better, the text is easy to follow and the theoretical explanations are clear even for those without extensive technical or mathematical knowledge.

The clinical applications of the magnification method are well presented and this description could be of great value to anyone wishing to utilize this method. The authors use a series of 14 patients to show the information gained by magnification in clinical practice. The film reproductions are excellent and clearly show the advantages of magnification in many fields of radiology. The information is based upon various focal spot sizes.

The authors have extensive personal experience in this field and S. Takahashi, the senior author, is one of the pioneers. The list of 141 references includes 20 of Takahashi's works and seven of these were written in collaboration with S. Sakuma, another pioneer with an extensive bibliography in this field. The fact that of 68 quoted papers of Japanese origin only 25 are in English enhances the value of this work since many critical references are in Japanese and this is the first comprehensive review of these in English.

Despite the obvious advantages and information so well described in this book, the present reviewer feels that the authors are somewhat overoptimistic and uncritical about the method. At the present time the use of magnification must be limited because of the radiation dose and because of the small field size.

In summary, this book is an excellent introduction to magnification radiography and reveals the great potentialities of the method.

Erik Boijsen

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SUBINTIMAL INJECTION OF CONTRAST MEDIUM AS A COMPLICATION OF SELECTIVE ABDOMINAL ANGIOGRAPHY

K JONSSON A LUNDERQUIST H PETTERSSON and B SIGSTEDT

Subintimal injection of contrast medium has been considered to be a minor complication in angiography although single isolated case reports have shown that the sequelae may be serious (ENGBERG et coll 1974 GILL et coll 1972) Therefore it was considered of value to evaluate (1) the frequency of subintimal injections in selective abdominal angiography (2) the reason of the injury and (3) the sequelae of the subintimal injection as demonstrated in subsequent angiography at operation or in other clinical and laboratory examinations

Material and Methods

Material I At the University Hospital in Lund an attempt has been made to analyse the reason of subintimal injections observed during angiographic procedures or at following clinical and laboratory examinations during a one year period At each angiographic examination a form with a number of specified questions on different complications had to be filled in and this material was used to evaluate the frequency of subintimal injections of contrast medium in selective abdominal angiography

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Fig. 1. 19-year-old female with nephrosis. Nephroangiography was indicated because of possible renal vein thrombosis. a) A subintimal injection was produced at test injection in the right renal artery. b) A subsequent aortography revealed total occlusion of the renal artery. An emergency operation disclosed clots in the main renal artery as well as in peripheral branches and no perfusion could be achieved. Nephrectomy was performed and microscopy demonstrated chronic proliferative glomerulonephritis.

Thus all catheterizations and subsequent injections of contrast medium performed in the celiac trunk and its divisions and subdivisions, in the superior and inferior mesenteric and the renal arteries were recorded. If more than one injection was performed with the catheter in the same position in the artery it was recorded as one catheterization. All examinations where subintimal injection of contrast medium was registered have been reviewed.

Material II consisted of an analysis of the immediate and late sequelae of the complication. All films, clinical records and laboratory reports from cases at the University Hospital and Malmö Allmänna Sjukhus, where a subintimal injection was followed by further contrast medium injections in the same vessel and at the same sitting or by a repeat angiography at a later event have been reviewed retrospectively. The cases of Material II were collected from a review of the angiography protocols at the two hospitals. Two patients received their injury when investigated at local hospitals, but follow up examinations were performed in Malmö.

Material II covers a 5-year period. Material I is collected from the last year of this period. Four patients from Material I are also included in Material II.

Results

The results obtained in material I is accounted for in Table 1. Among 1 804 catheterizations subintimal injection was observed in 37 cases. In 10 of these, the corr

Table 1

Subintimal deposits of contrast medium Material I

Vessel	No of catheterizations	No of subint deposits	Per cent	Reason of injury		
				Guide wire	Catheter	Uncertain
Coeliac trunk	442	5	1 1		2	3
Hepatic art	250	14	5 6	9	3	2
Splenic art	45	2	4 4	1		1
Gastroduodenal art	44	3	6 8	2		1
Dorsal pancreatic art	8	[illegible]				
Post sup pancreatico-duodenal art	1	1	20	2		
Jejunal art	1	1				
Left gastric art	29	2	0 9	1		1
Superior mesenteric art	361	1	0 3	1		
Inferior mesenteric art	40	3	7 5		3	
Renal art.	583	5	0 9		5	
Total	1 804	37	2	16	13	8

Table 2

Immediate control of subintimal deposit of contrast medium Material II

Vessel	Increase of subintimal deposits of contrast medium or occlusion	Decrease of subintimal deposits of contrast medium	Unchanged
Coeliac trunk			1
Hepatic artery	5	1	1
Gastroduodenal art	1		1
Pancreaticoduodenal art		1	
Sup mesenteric art	2		
Renal art.	4	1	1
Total	12	3	4

plication was registered at fluoroscopy without film documentation while in 27 it was visible on angiography films

The injury and subsequent subintimal injection was considered to be caused by the guide wire in 16 instances the catheter in 13 and was uncertain in 8

In material II an immediate angiographic control of the complications was performed in 19 patients (Table 2) The lesion appeared worse in 12 patients unchanged in 4 and decreased in 3 Of the 12 patients additional subintimal deposition

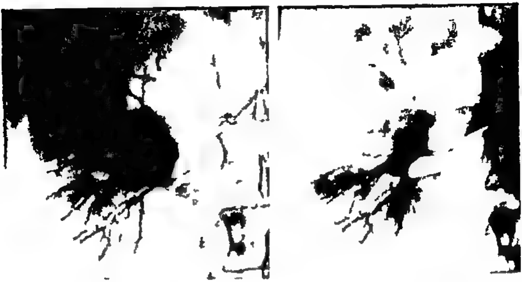

Fig. 2. 45 year-old female with macroscopic haematuria and right sided pain Cystoscopy revealed a clot from the right ureteric orifice a) The tip of the catheter injured the right renal artery and a subintimal injection followed b) At a subsequent series several clots in the main arteries and occlusion of small intrarenal branches are demonstrated

of contrast medium occurred in 7 at the repeat injection and in 5 a total occlusion of the vessel developed

In 6 patients with lesion of the renal artery 2 had total occlusion at a following aortography (Fig 1) and one of them was operated upon as emergency At operation extensive thrombosis was found in the main and peripheral vessels In another patient with injury to the renal artery aortography demonstrated extensive thrombosis in the main and peripheral vessels In still another patient the subintimal lesion increased in a following selective catheterization and a few clots were demonstrated in the renal artery (Fig 2) In one patient the injury was less evident in the following series and in another no change was observed between the series

Repeat angiography at a later event was obtained in 11 patients and of these the injury was in the celiac trunk or the hepatic artery in 7 in the superior mesenteric artery in 2 and in the inferior mesenteric artery in 2 In 7 patients with injury to the celiac trunk or the hepatic artery the immediate result was total occlusion of the vessel in 5 and narrowing in 2 At repeat angiography the occlusion persisted in 2 patients 3 and 14 weeks after the injury In 3 patients the lumen of the vessel had been recanalized with slight to moderate irregularity of the wall after 2 1/2 12 and 15 months, respectively The patient who was examined after 2 1/2 months was re examined 24 months after the injury and the vessel was then entirely normal (Fig 3) Two patients with narrowing of the vessel were re-examined after 2 and 3 months

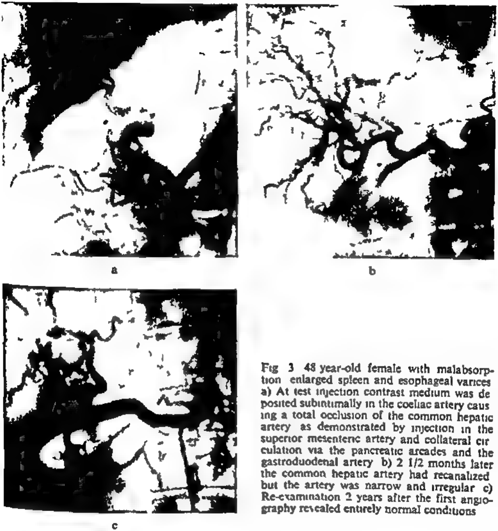

Fig 3 48 year-old female with malabsorption enlarged spleen and esophageal varices a) At test injection contrast medium was deposited subintimally in the coeliac artery causing a total occlusion of the common hepatic artery as demonstrated by injection in the superior mesenteric artery and collateral circulation via the pancreatic arcades and the gastroduodenal artery b) 2 1/2 months later the common hepatic artery had recanalized but the artery was narrow and irregular c) Re-examination 2 years after the first angiography revealed entirely normal conditions

respectively and the narrowing still persisted although to a lesser extent Two patients with injury of the proximal part of the superior mesenteric artery developed aneurysms causing stenosis of the artery (Fig 4) These aneurysms were found at re-examination after 1 1/2 and 55 months respectively Repeat angiography was performed in 2 patients with subintimal injection of the inferior mesenteric artery In one an occlusion existed after 5 days but 5 years later normal conditions were revealed In the other patient contrast medium was also injected subintimally in the aortic wall close to the vessel Five weeks later an aneurysm was demonstrated in the proximal part of the inferior mesenteric artery and a stenosis of the vessel distal to the aneurysm

a b c

Fig. 4. 45 year-old female with non-specific abdominal pains of long duration. a) A subintimal injection was produced in the proximal part of the superior mesenteric artery. The patient then experienced a new kind of pain in the abdomen. b–c) Re-examination 5 years later revealed an aneurysm of the artery compressing its main stem.

Altogether 9 patients had a renal artery injury (2 patients are included in both materials).

The clinical and laboratory follow up included isotope nephrography in one patient with complete occlusion of the left renal artery. The uptake of that kidney was highly impaired immediately after angiography. It improved slowly but never reached normal values. That patient had hypertension before and after the angiography. In 2 patients with injury to the renal artery nephrectomy was performed (one as an emergency and the other because of renal carcinoma).

One patient with renal artery injury had normal blood pressure 1 1/2 years later while no pressure measurements have been performed in the other 5 patients with renal artery injury.

The complaints of the patients after the arterial injury were small. In spite of sometimes extensive extravasation of contrast medium (Fig. 5) most patients had no discomfort whatsoever. However, one patient with occlusion of the hepatic artery had considerable abdominal discomfort for one week, while a few others had short burning pain only. In none of the patients with subintimal injection the angiography revealed a severe degree of atherosclerosis.

Discussion

Subintimal injection of contrast medium has been considered as a minor complication in angiography (McAfee 1957, Lang 1963) and it has only sparsely been mentioned in reports on complications in angiography. When described it usually concerns subintimal dissection of the aorta or the iliac arteries (Bilan et coll. 1969

Fig 5 60-year-old male with a right-sided renal carcinoma operated upon 1 year previously In the search for hepatic metastases a coeliac angiography was performed and during the procedure an extensive extravasation of contrast medium was produced following injection into the splenic artery The patient experienced no pain or discomfort

BOLASNY & KILLEN 1971 GILLANDERS 1963 GREENSTONE et coll 1965 GUDBJERG & CHRISTENSEN 1961 McGRAW 1963 RASCHKE & MAURER 1967)

The occurrence of subintimal injection is said to be due to improper technique (LANG 1963) It is felt that the complication discredits the angiographer and this may be a reason why so little is reported on this type of complication The true view of the frequency of complications at angiography is only obtained if a careful and honest registration during the angiography is performed as well as a careful clinical follow up of the patients

An attempt was made to analyse the reason of the injury In the 37 patients in material I 16 lesions were considered to be due to the guide wire 13 to the catheter while the reason was uncertain in 8 cases A significant increase of lesions occurred in more selective examinations and particularly in those of smaller vessels This is explained by the technique of introduction of the guide wire beyond the catheter tip to guide the catheter to a superselective position In such cases the tension between the bends of the catheter the guide wire and the walls of the vessels seemed to cause lesion of the intima It is thus the technique of superselective catheterization in combination with anatomic conditions that results in subintimal deposit of contrast medium at the ensuing angiography in most cases In renal and inferior mesenteric arteries neither the size nor the superselectivity seems to be a predisposing factor but the tortuosity of the vessel

ENGBERG et coll (1974) and GILL et coll (1972) have described total occlusion of the renal artery following subintimal injection and subsequent clot formation at the location of the lesion Such sequelae were found in the present material both at operation and at angiography and were also demonstrated in one patient by isotope nephrography Renal arteries seem to be at high risk for clot formation with subsequent embolization and infarction of the kidney This has been shown also experimentally in the dog (LDLING & OVENFORS 1964) However from the current litera

ture and the present material it is not clear whether an acute operation is indicated in all these cases as the operative finding may be unremarkable (REISS et coll. 1972, TALNER et coll. 1975). The position of the catheter tip must always be carefully checked before injection especially in a curved renal artery. Once a subintimal injection has been performed in a renal artery no further catheterization or injection of contrast medium in that vessel should be performed. Aortography may, however, be of value to demonstrate if an occlusion of the artery has occurred (TALNER et coll. 1975).

GILBERT & MELNICK (1965) have described the occurrence of subintimal hematoma during retrograde catheterization of the ascending aorta or the aortic arch. They felt that the injury was due to the tip impaction velocity in the aorta. This mechanism seems to have little in common with the type of lesion produced in selective angiography. Atherosclerosis does not seem to be an important predisposing factor of this type of injury in selective angiography contrary to what pertains to aortography (GREENSTONE et coll. 1965, GUDBJERG & CHRISTENSEN 1961, RASCHKE et coll. 1967).

The late sequelae of subintimal injections in angiography have seldom been reported in the literature. The occlusion of the hepatic artery with secondary rapid development of collaterals has been described by REUTER (1966).

The present series demonstrate that the occlusion may remain for several months but the collaterals seem to furnish satisfactory blood supply and no injury to the liver occurs. In many cases the artery will recanalize within a few months and finally the vessel is completely normalized (Fig. 3). Thus a lesion of the hepatic artery and its branches does not have as serious consequences as in the renal arteries, but it is to be recommended not to continue the examination of the vessel once a lesion of the artery is recognized.

Aneurysms in the superior mesenteric artery are rare (REDMAN & REUTER 1970). Two patients developed such aneurysms in the proximal part of the artery causing narrowing of the more distal part. In such cases collaterals from the celiac trunk via the pancreatic vessels open and dilate immediately and provide for a large part of the blood supply to the mesenteric region. Several injections were performed in all the patients with lesion of the superior mesenteric artery after the injury had occurred, presumably because it was overlooked. This injury has more serious consequences because of the tendency to aneurysm formation and once injury to this artery is recognized the examination should be discontinued.

The frequency of subintimal injections in angiography increases rapidly with the degree of selectivity and with the size of the vessels examined. The sequelae of such injury in the celiac hepatic arteries seem to be of minor clinical importance because of the collaterals and reparative function of the body. In the renal, superior and inferior mesenteric arteries the sequelae may be serious causing clinical trouble.

In order to reduce the number of complications it is important to analyse their origin.

Most injuries were produced when it was tried to pass the catheter through the tortuous artery. If the guide wire is inserted through a catheter with the tip against

the wall of the artery an intimal injury is difficult to avoid even if the guide wire has a soft tip An injury is also easily produced if a catheter with a long descending part is pulled into a short celiac artery with obtuse branching into splenic and hepatic arteries It is more probable that the tip is placed against the wall in a tortuous artery than in a straight one When a tortuous artery is to be catheterized it is suggested to insert the soft tip of a guide wire with a movable core 2 to 3 cm beyond the tip of the catheter to show the way through the curves If spasm occurs it seems advisable not to try to pass the constricted vessel with the catheter

Already at the introduction of the catheter into the main branches of the aorta intimal tears may be produced if the curve of the catheter is too wide or the descending part too long in comparison with the diameter of the aorta

It seems also important not to struggle too long a period of time to perform a superselective examination if the anatomy is not favourable In renal arteries the use of a curved catheter with a long soft tip has proved to be excellent and to minimize the risk of subintimal injection The first angiographic series must be scrutinized to recognize an injury before the examination is continued

The development of aneurysms in the superior mesenteric artery were in both cases preceded by multiple subintimal deposits of contrast medium in the vessel presumably not observed in the first instance As a rule it must be stated that once an injury is discovered no further catheterizations or injections in that vessel should be performed

SUMMARY

The frequency cause and sequelae of subintimal injection of contrast medium as a complication of selective abdominal angiography have been evaluated The frequency increased considerably with the degree of superselectivity The risk of total occlusion and clot formation in the renal artery after subintimal injection is high Injury and total occlusion of the celiac and hepatic arteries have better chance for healing than of the renal arteries A subintimal injection in the proximal part of the superior mesenteric artery may result in the development of an aneurysm

ZUSAMMENFASSUNG

Die Haufigkeit Ursache und Folgen der subintimalen Injektion von Kontrastmittel als eine Komplikation der selektiven abdominalen Angiographie wurden festgestellt Die Frequenz stieg wesentlich mit dem Grad der Superselektivitat Das Risiko des totalen Verschlusses und der Thrombose der Nierenarterie nach subintimaler Injektion ist hoch Verletzung der Bauchholen und Leberarterien haben bessere Aussichten einer Heilung als die der Nierenarterien Eine subintimale Injektion in den proximalen Teil der oberen mesenterialen Arterie kann zur Entwicklung eines Aneurysmas fuhren

RESUME

Les auteurs ont etudie la fréquence les causes et les sequelles de l injection sous intimale de moyens de contraste comme complications de l angiographie abdominale selective Sa

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RESUME

Les auteurs ont tudie la frequence les c.u s et les sequelles de l injection sous intimale de moyens de co traste comme complicatic.ns de l angiographie abdominale selective Sa

fréquence augmente considérablement avec le degré de supersélectivité Le risque d occlusion totale et de formation de caillots dans l artere rénale après injection sous intimale est élevé Les lesions et l occlusion totale des artères coeliaque et hepatique ont de meilleures chances de guérir que celles des artères rénales L injection sous intimale dans la partie proximale de l artère mesenterique superieure peut aboutir au developpement d un anévrysme

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FROM THE TRENT REGIONAL DEPARTMENT OF NEUROSURGERY AND NEUROLOGY AND THE MEDICAL PHYSICS DEPARTMENT DERBYSHIRE ROYAL INFIRMARY DERBY DE1 2QY ENGLAND

BRAIN SCAN AS AN AID IN THE DIAGNOSIS OF ACOUSTIC NEUROMA RECURRENCE

R H SHEPHARD W H HOATHER and T MCKENZIE

The efficiency of radioactive brain scanning in the detection of acoustic neuromas is now accepted and BAUM et coll (1972) drew attention to its particular application to tumour recurrence The present paper shows the results in a series of 34 patients from whom acoustic neuromas had been removed In contrast to the acknowledged drawbacks and disadvantages of the more standard investigations in recurrent acoustic neuroma the ease of performance of brain scanning and its complete safety and lack of discomfort offer an ideal method in this situation The impetus to carry out this investigation was based on the experience of two patients with recurrent tumours seen within a brief interval The tumours recurred five and seven years after the initial operation and were evident clinically the scan serving merely to confirm the diagnosis

There appeared to be a distinct possibility of other patients having recurrent tumours which were as yet clinically silent and it seemed that a deliberate programme utilising the scanning technique at intervals could be mounted to anticipate the appearance of unequivocal symptoms of tumour recurrence A close clinical assessment has been maintained over the years of all survivors of acoustic neuroma surgery and during this investigation they have been re-examined for correlation of the clinical findings with the scan appearance

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fréquence augmente considérablement avec le degré de supersélectivite Le risque d occlusion totale et de formation de caillots dans l artere rénale après injection sous intimale est élevé Les lesions et l occlusion totale des artères coeliaque et hépatique ont de meilleures chances de guérir que celles des artères renales L injection sous intimale dans la partie proximale de l artère mésenterique supérieure peut aboutir au developpement d un anévrysme

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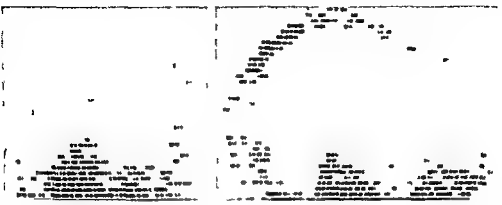


Fig. 1 Scan 5 years after removal of tumour from right side Increased uptake in the cerebello-pontine angle

the initial operations varied from moderate to large size—within Drake s clinical categories III or IV

Of the 34 survivors complete removal had been carried out in 21 cases but in 13 a result short of this was accepted and small adherent tumour residues left on the brain stem because of alarming ECG changes with manipulation and risk to the brain stem vessels Three of the 13 were operated upon a second time for recurrence It is of interest that these 3 were among the youngest members in the series their ages being 32 32 and 42 at the initial operation In each a complete removal was achieved at the second operation 4 5 and 7 years respectively after the original operation

Results

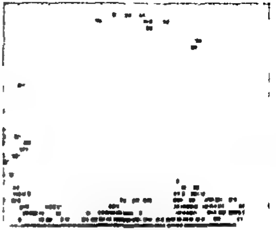
Postoperatively 33 of the 34 patients were scanned and in addition further scans were performed in 9 of the patients Scans were classified as positive doubtful, or negative with respect to the uptake of the isotope in the cerebellopontine angle

Group I Positive scans (4 cases) were found in 2 cases with a tumour recurrence and in a third case with remaining tumour in the fourth case the significance of the positive scan was uncertain

The patients with recurrent tumours were 2 of the 3 who were operated upon a second time (the third was not scanned as facilities were not available) All 3 had negative scans after the second operation

In the third patient it was known that a large part of the tumour remained left deliberately because of difficulty during the operation The fourth patient had a total removal of the tumour but has had two positive postoperative scans the first 2 years after operation and the second 9 months later This patient 46 years old had no clinical evidence of recurrence and is leading a normal life which includes a career

Fig 2 Patient aged 25 negative scan 4½ years after total removal of tumour from right side



in teaching The significance of the positive scans is uncertain but the area of abnormal uptake was more marked than would seem likely from a recurrent growth of tumour after the relatively short interval of 2 years The absence of significant change in the 9 month interval between the two positive scans seems to support this contention

Group II Doubtful scans (3 cases) One patient had acoustic neuromas removed from both sides and 5 years later a doubtful uptake of isotope was found on the side from which the tumour was removed first One patient with a subtotal excision of an acoustic neuroma at age 55 remains well It is uncertain whether the doubtful scan 8 years later is due to the slight fragment of tumour remaining or to its growth since but a repeat scan after a further 2 year interval was negative Another patient was 57 years old at the time of operation and well when scanned 8 years later but the scan was evaluated as doubtful All 3 patients are still well and without clinical evidence of recurrence

Group III Negative scans (26 cases) Of these 11 were scanned between 9 months and 7 years after operation and the remainder between 7 years and 13 years A total removal of the tumour was performed in 19 cases and a subtotal in 7 cases One negative scan is shown in Fig 2

The results of the 33 cases are summarized in Fig 3 where the distribution of cases is plotted against the postoperative time interval of the scan The number in each square indicates the age of the patient at operation

Discussion

The conventional radiologic techniques available for determining the presence of recurrent acoustic neuromas all carry a risk and always result in some discomfort

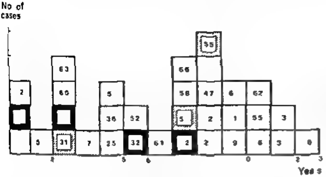


Fig 3 Distribution of cases and the postoperative time interval of the scan The number in each square indicates the age of the patient at operation Black indicates positive hatched doubtful and white negative scans

Brain scanning is free of such risk and discomfort and with proper technique a success rate of 86 to 100 per cent is claimed in the diagnosis of acoustic neuroma (BAUM et coll 1972 DELAND & WAGNER 1969) This applies to tumours 2 cm in diameter or larger and as such is highly relevant to British neurosurgical practice where smaller tumours are still a rarity In one only of the 39 patients was the tumour of this small size (2 cm) and patients developing unilateral deafness often regard it as a fact of life and so fail to attend for medical advice until some additional symptom occurs

Heretofore the only clue to tumour re growth was the appearance of symptoms after a period of clinical stability or progressive improvement and by then the tumour had usually attained or even exceeded its previous size The planned use of the scan as part of the follow up programme would serve to avoid this situation Whilst it may be argued that the scan is ineffective for tumours below 2 cm in diameter the older methods are even less satisfactory as stated by BAUM et coll In particular positive contrast cisternography which alone approaches brain scanning in accuracy is less reliable after the effects of surgery have been superimposed this fact and the risks involved render it impracticable for routine screening

A craniectomy may possibly influence the scan Therefore the scans were compared with the postoperative skull films and in the majority of cases there was no evidence to indicate that the craniectomy affected the scan However in some cases with negative scans concerning the appropriate cerebellopontine angle there was increased uptake around the operation site This effect occurred in scans ranging from one month to 11 years after operation It can be distinguished from uptake in the cerebellopontine angle by a careful comparison of the posterior and lateral scans HURLEY (1972) reported that a craniectomy could be visible on a scan after 24 years although the site was not specified

Therefore it is difficult to specify any optimum time interval for an early post operative scan but the secondary effects of surgery appeared to be most noticeable in 2 cases of early scans carried out within 2 months of operation Accordingly a longer time interval of say 6 months would seem appropriate for a postoperative scan as a check for reference to the region of the angle in the future scans

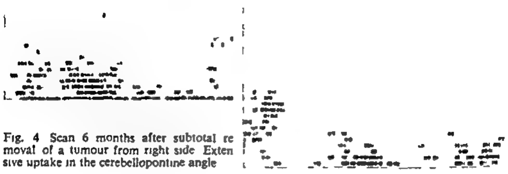


Fig. 4 Scan 6 months after subtotal removal of a tumour from right side Extensive uptake in the cerebellopontine angle

The optimum time interval between the administered dose of isotope and the commencement of the scan has been investigated by several workers (BAUM et coll DELAND & WAGNER) A short interval is desirable because of the short half life of $^{99}Tc^{m}$ but the *possibility of a slow uptake of isotope in the cerebellopontine* angle must be considered In the present series the scanning sequence for the 3 views was normally left right and posterior and the time interval after dose was approximately ½ h 1 h and 1½ h respectively In the case of a scan for a left sided recurrence a repeat left scan was sometimes carried out after the posterior view but no difference could be detected between the early and late scan Therefore it was felt that the timing sequence used was satisfactory but that the lateral view should be repeated if any abnormality is visible on the posterior view which was not demonstrated on the first lateral

Concerning the age of patients and recurrence it should be noted that the 3 patients with recurrent tumours in this series were in the younger age group ages varying from 32 to 42 years VALVASSORI (1969) though dealing with patients in a younger age group than the present ones speculated on the possibility of more rapid and destructive growth of the tumour in young people and the 3 examples of recurrence in the present series serve to support this Clearly these patients are at greatest risk and in them the planned use of the isotope screening test is likely to be of especial merit

In 7 of the 26 patients with negative scans only a subtotal removal of tumour was carried out It is possible that in some of these cases although tumour growth has continued the tumour is still smaller than 2 cm in diameter It is also conceivable that in others tumour growth has actually regressed from lack of blood supply thus accounting for the negative brain scan This second alternative seems more likely in view of the fact that in 5 out of the 7 cases with subtotal removal the postoperative time interval of the scan ranged from 8 to 13 years For the remaining 2 cases it was 3 and 4 years The use of serial scanning may help to elucidate this point

The possibility of necrosis is also illustrated by the progress of one patient in

Group I This was a man of 57 from whom only subtotal removal (approximately two-thirds) of a large acoustic neuroma was carried out Six months after the operation a fairly extensive uptake of the isotope was found in the cerebellopontine angle (Fig 4) A further scan 2 years later showed an improvement During the same 2 year period his clinical condition has improved

The following recommendations seem to be appropriate The first scan after operation should be delayed for 6 months—to allow the effects of the craniectomy to subside Subsequent scans are performed at intervals depending upon the age of the patient amount of tumour removed result of first scan and clinical course

(1) For patients over age of 30 tumour removal complete Initial scan negative	Scan at 3 to 4 year intervals
(2) Patients *under 30 incomplete tumour removal* Initial scan positive	*Yearly scan* review in 3 to 4 years if negative
(3) Scan initially positive becoming negative	Increase scan interval (to 3 to 4 years)

An earlier scan would be performed at any time on the appearance of clinical manifestation of recurrence Further investigation and operation will naturally be considered in the following (1) Patients with known tumour residues and scans indicating further growth (2) Patients with scans initially negative and later positive (3) Patients with clinical evidence of recurrence whether scan positive or negative

Conclusions

(1) Positive scans occurred in 2 out of 3 cases of confirmed recurrent acoustic neuroma (the third was not scanned)

(2) In a number of other patients with residual tumour at the initial operation the scans were normal several years later The possibility of necrosis of the tumour residue in such cases is supported by the results of successive scans in one patient

(3) The results of the analysis have led to the formulation of a policy of periodic scanning as an integral part of the follow up programme of acoustic neuroma patients This policy has been set out in the discussion

Acknowledgements

We are grateful to the staff of the Medical Physics Department P A Carrington and S A Collis for carrying out the scans and to the neuroradiologist R. Whitaker for helpful discussions on many of the scans

SUMMARY

Brain scans using $^{99}Tc^{m}$ were performed on 34 patients from whom acoustic neuroma had been removed The age range was 19 to 66 years at the time of operation The scans were carried out at intervals up to 13 years postoperatively There were 4 positive 3 doubtful and 26 negative scans A policy is formulated for periodic scanning as an integral part of the follow up programme of acoustic neuroma patients

ZUSAMMENFASSUNG

Gehirnszintigraphie unter Verwendung von $^{99}Tc^{m}$ wurde bei 34 Patienten bei denen ein Acusticusneurom entfernt worden war vorgenommen Der Altersbereich betrug 19 bis 66 Jahre zur Zeit der Operation Szintigraphie wurde in Intervallen bis zu 13 Jahre postoperativ ausgefuhrt Vier Szintigraphien waren positiv 3 zweifelhaft und 26 negativ Ein Programm fur die periodische Szintigraphie als ein integrierter Teil einer Nachuntersuchung von Patienten mit einem Acusticusneurom wird formuliert

RESUME

Des scintigraphies cerebrales au $^{99}Tc^{m}$ ont été faites a 34 malades ayant subi l exérèse d un neurinome de l auditif Leur age au moment de l operation allait de 19 à 66 ans Les scintigraphies ont eté faites avec des délais post opératoires allant jusqu à 13 ans Elles ont eté positives dans 4 cas douteuses dans 3 et negatives dans 26 cas Les auteurs définissent un programme de scintigraphie périodique faisant partie intégrante de la surveillance des malades ayant eu un neurinome de l auditif

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Book review

Advances in Cerebral Angiography Edited by G Salamon Institut National de la Sante et de la Recherche Médicale 378 pages with 222 figures Springer Verlag Berlin Heidelberg New York 1975 Price DM 59 80

The book contains the papers from the INSERM Symposium held in Marseille in 1975 and is published as an offset print of great clarity The illustrations are of a high class and references are given to every paper The volume contains valuable contributions to vascular anatomy embolization technique brain circulation stereotaxy and computer tomography The Symposium thus covers a vast region of cerebral angiography with a stress on modern aspects

A large part of the volume deals with vascular anatomy and the application of stereo tactic technique to carotid angiography Of great interest is the detailed correlation between the surface anatomy of the brain i e the gyri and sulci and the cortical arteries Emphasis is made on the use of magnification stereoscopy and subtraction techniques as well as angiotomography in order to locate the majority of the fissures and sulci on the brain surface

The extension of the vascular territories are given as well as a comprehensive description of the anatomy and topography of the central arteries of the brain The displacements of the thalamo perforating arteries caused by expanding lesions in the third ventricle thalamus and mesencephalon are discussed The use of angiotomography and magnification techniques in the localisation of tumours as well as hemorrhages are stressed

The anatomy of the arteries of the posterior fossa are discussed and special concern has been given to the anterior inferior cerebellar artery and its variations as well as to the arteries to the internal auditory canal A detailed description is also given of the normal variations of the basal cerebral veins

In the part dealing with technical advances emphasis has been laid on the use of magnification technique angiotomography stereotactic angiography selective venous and super selective arterial injections as well as therapeutic arterial embolization Superselective examinations of the orbital and basal veins as well as examination of branches of external carotid arteries is discussed

Embolization technique superselectively in the external carotid artery as well as in the internal carotid artery is discussed by Djindjian The balloon-catheter technique introduced by Serbinenko has been applied by Djindjian and de Brun

In the part dealing with stereotaxy the use of stereotactic technique applied to carotid angiography is shown with excellent results In order to make use of all information inherent in a serial angiography it seems that the method used by the French colleague is superior to the conventional method In the future when the CT scan will make most of the diagnostic assessment angiography must be performed in such a way that it facilitates the extraction of the necessary information regarding the topography of a tumour vis a vis the vessels This can be done by the use of the stereotactic technique in combination with angiography

CT scan and angiography is discussed and aspects on cerebral angiography in the pediatric patient is likewise reported as well as single articles dealing with such problems as congenital anomalies vein pathology angiography and examination of brain injury

The book contains a vast amount of new information regarding cerebral angiography with stress on detailed anatomy necessary for advanced diagnostic and therapeutic work Thus embolization needs a technique for detailed anatomic analysis of arteries to the brain as well as to the meninges Likewise stereotactic surgery and microsurgery has a need of detailed information which cannot be obtained by conventional technique For this purpose detailed anatomic investigation into all vascular territories of the brain is a prerequisite be

it the neurosurgeon with his microscope or the neuro radiologist with the floating balloon catheters that takes advantage of it

The impact on diagnostic neuroradiology made by CT scanning is great but in my opinion the work reviewed without doubt indicates that carotid angiography still is a necessary procedure and that the contribution of CT scan probably will be a further incidence for the use of carotid angiography in a more sophisticated way than has been the case hitherto

The volume is recommended to all engaged in diagnostic neuroradiology

Bengt Liliequist

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POSTOPERATIVE KINEMATICS IN STRUCTURAL SCOLIOSIS

T H OLSSON G SELVIK and S WILLNER

The results of scoliosis treatment are difficult to evaluate (ROAF 1966 BLOUNT 1973 HINDMARSH 1973) Using roentgen stereophotogrammetry OLIN et coll (1976) demonstrated experimentally that accurate kinematic analysis of scoliosis is possible In other experiments OLSSON et coll (1976 a b) demonstrated that residual mobility between vertebrae operated upon with fusion are possible to detect and quantify by this method It was therefore applied to 3 cases with idiopathic structural scoliosis to evaluate the effect of the fusions on the scoliotic curvatures The observation time is however as yet only one year

Material and Methods

The material consisted of 3 patients Originally also a fourth case was operated upon but this case had to be excluded because the indicators were by mistake placed close to a straight line in two of the vertebrae and because one indicator in another segment was hidden behind the Harrington rod The scoliosis was measured by the method of COBB (1948) The three cases had a right convex thoracic idiopathic scoliosis in the first case (girl aged 15) located at Th 6–L 1 and measuring 54 in the

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it the neurosurgeon with his microscope or the neuro radiologist with the floating balloon catheters that takes advantage of it

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Bengt Liliequist

Table

The mean errors of rigid body fitting (e_{rb}). Each value is given separately for the supine positions indicated. For the supine standing and the various standing positions they are given as mean values and their standard errors. In the precision test two evaluations of the same film are compared with each other and the mean and standard errors for seven such re-evaluations are given (unit μm)

		Supine positions			The supine standing and standing positions	Precision test
		1–2	1–3	2–3		
Case 1	Th5	378	430	71	57±19	40±16
	Th7	99	105	42	34±17	44±35
	Th10	227	176	55	35±15	41±17
	Th11	240	250	12	22±8	31±16
	L2	134	160	29	47±17	35±15
Case 2	Th4	143	171	51	36±11	
	Th5	114	128	26	33±14	
	Th10	253	267	90	81±37	
	Th11	210	153	64	41±12	
	L2	40	76	52	65±21	
Case 3	Th3	86	128	50	71±28	
	Th4	—	—	—	49±22	
	Th9	51	13	194*	59±22	
	L2	24	52	42	47±12	

* Two indicators were partly superimposed at the third examination

Results

The mean errors of rigid body fitting (e_{rb}) and the contribution of measurement errors to these e_{rb} (as calculated from the precision test) are accounted for in the Table. For the supine examinations each value is given separately. For the supine to standing and the various standing positions the e_{rb} are given as their mean values and standard errors. The reason is that some of the values (e_{rb}) of cases 1 and 2 at the first supine examination were high compared to the values at the other two examinations (<430 μm). For the supine to standing and the various standing positions these values were, however, within the limits for the contribution of measurement errors.

From the precision test the errors 0.24°, 0.23° and 0.08° were obtained for the rotations about the x, y and z axes respectively and the errors 292, 144 and 526 μm for the translations along the same axes for the motions between Th5–L2. These segments are located at both ends of the examined part of the spine 230 mm apart. The angular errors were utilized to determine significant ($p<0.01$) motions in all three cases by means of the Student's t test.

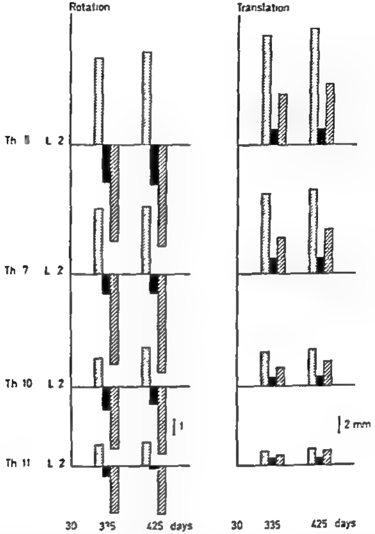


Fig. 1 Case 1 The rotations and translations for the segment pairs given as computed for the supine positions 335 and 425 days postoperatively in relation to the supine position 30 days postoperatively Stippled staples represent the rotations and translations about and along the x axis filled staples represent the motions relative to the y axis and striped staples the motions about and along the z axes. Operation performed between Th5 and L2.

Case 1 The rotations and translations between the supine position 30 days postoperatively and the other two supine positions (335 and 425 days postoperatively) appear in Fig 1 where each staple group represents the motion of one vertebra in relation to the lowermost vertebra The vertebrae Th5 Th7 Th10 and Th11 have rotated forwards about the x axis relative to L2 ($\alpha_x < 5.3$ stippled staples) between the first and the second examinations clockwise about the y axis ($\alpha_y \geq -2.4$ filled staples) and to the left about the z axis ($\alpha_z \geq -6.0$ striped staples) The simultaneous translations show that the vertebrae mentioned have moved towards the left along the x axis ($d_x \leq 13.5$ mm) cranially along the y axis ($d_y < 2.0$ mm) and forwards along the z axis ($d_z \leq 7.5$ mm) in relation to L2 No significant motion

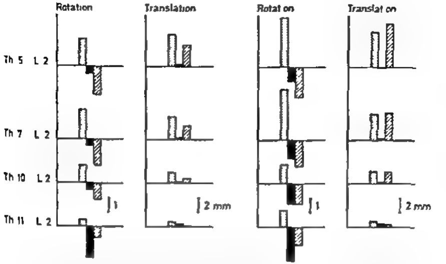


Fig 2. Case 1 335 and 425 days postoperatively respectively The rotations and translations between the supine and the erect standing positions For explanation of the symbols see legend for Fig 1

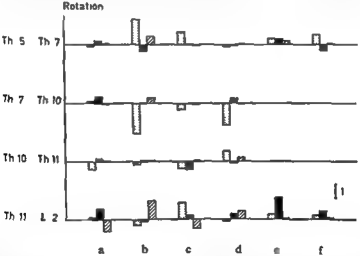
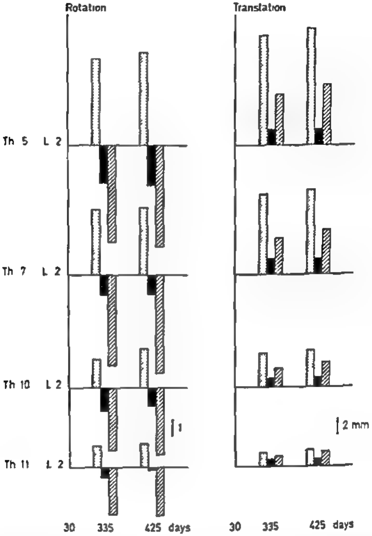


Fig 3 Case 1 425 days postoperatively The rotations for the standing positions given relative to the erect standing position The values significantly (p < 0 01) different from zero are marked (•) Four staple groups are absent because one indicator in Th10 was hidden behind the *Harrington* rod during the axial rotations a Lateral bending to the left b – Lateral bending to the right c = Flexion d = Extension e = Counter-clockwise axial rotation f = Clockwise axial rotation For explanations of the symbols see legend for Fig 1

occurred between the second and third examinations The rotations and translations continuously increased from the lowermost vertebra upwards i e the rotations and translations between each vertebra and its subjacent indicated vertebra are in one and the same direction Between the erect standing positions and the supine positions 335 and 425 days postoperatively additional motions took place in the same directions (Fig 2) Although greater at



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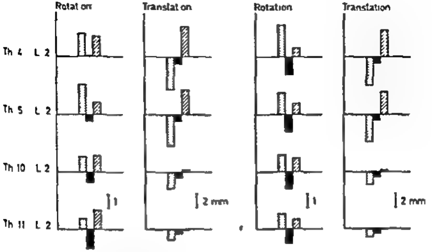

Fig 5 Case 2. 247 and 393 days postoperatively respectively The rotations and translations between the supine and the erect standing positions For explanation of the symbols see legend for Fig 1

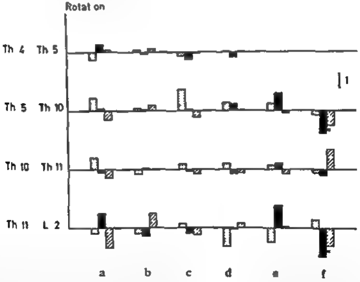

Fig. 6 Case 2 393 days postoperatively The rotations for the standing positions given relative to the erect standing position The values significantly (p 0 01) different from zero are marked (*) For explanation of the symbols see legends for Figs 1 and 3

($\alpha_z \geq -4.7$) Following these rotations t nslations towards the right along the x axis for Th10–L2 and for Th11–L2 and towa d the left above Th10 appeared The translations along the y axis were close to zero wh l the translations along the z axis were directed forwards ($d_z \leq 8.3$ mm) Though slightly magnified similar rotations and translations were recognized between the first and the third supine examination (23 and 393 days postoperatively) From the supine to the erect standing position there was at the two examinations

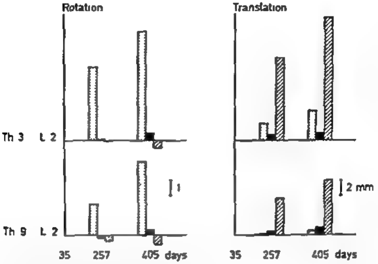

Fig. 7 Case 3 The rotations and translations for the segment pairs given for the supine positions 257 and 405 days postoperatively in relation to the supine position 35 days postoperatively Operation performed between Th3 and L2. For explanation of the symbols see legend for Fig. 1

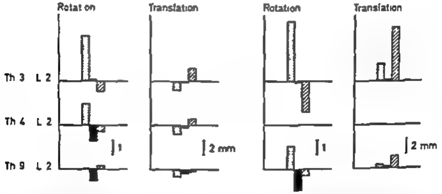

Fig. 8 Case 3 257 and 405 days postoperatively respectively The rotations and translations between the supine and the erect standing positions Two staple groups are absent because one indicator was hidden behind the Harrington rod during the supine position 405 days postoperatively For explanation of the symbols see legend for Fig. 1

247 and 393 days postoperatively an additional forward rotation about the x axis ($\bar{x}_x < 2\,2$) Slight additional clockwise rotation about the y axis was found between Th11–L2. It diminished in magnitude above this level at the examination 247 days postoperatively but was constant at the third one A rotation towards the right occurred about the z axis between Th11–L2 Corresponding to these rotations there were continuously increasing translations upwards from the lowermost vertebra towards the right along the x axis and forwards along the z axis and a slight downward translation along the y axis ($d_y > -1$ mm)

The motion obtained between the standing positions 393 days postoperatively appear in Fig. 6 where significant rotations are marked (**) Significant movements occurred between Th5–Th10 Th10–Th11 and Th11–L2.

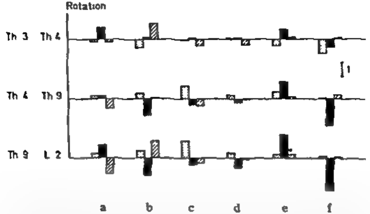

Fig 9 Case 3 405 days postoperatively The rotations for the standing positions given relative to the erect standing position The values significantly ($p < 0.01$) different from zero are marked ( ) For explanation of the symbols see legends for Figs 1 and 3

Case 3 The motions demonstrated between the supine positions 35 257 and 405 days postoperatively are given in Fig 7 Between the first and the second examination there were forward rotations about the x axis ($\alpha_x = 2.0$ for Th9–L2 and $\alpha_x = 4.7$ for Th3–L2) while the rotations about the y and z axes were close to zero Between the first and the third examination the forward rotations had increased ($\alpha_x = 4.7$ for Th9–L2 and $\alpha_x = 6.9$ for Th3–L2) The corresponding translations showed slight movements toward the left along the x axis and forward movements along the z axis ($d_z < 15.5$ mm) The translation along the y axis was less than or equal to 1.0 mm The forward rotations about the x axis demonstrated 257 and 405 days postoperatively increased further in the erect standing positions (Fig 8) In addition there were clockwise rotations about the y axis between Th9–L2 A rotation towards the left about the z axis was found 405 days postoperatively between Th3–L2 ($\alpha_z = -2.1$)

The rotations between the standing positions examined 405 days postoperatively appear in Fig 9 where significant rotations are marked (*) Such rotations were demonstrated in all three intervals (Th3–Th4 Th4–Th9 and Th9–L2)

Discussion

The comparison between the mean errors of rigid body fitting (e_b) and the contribution of measurement errors to these e_b (Table) reveals no or only slight evidence that the indicators of Th7 and L2 in case 1 Th4 Th5 and L2 in case 2 and the three segments in case 3 did not behave according to the rigid body model However some mutual motion may have occurred between the indicators in Th5 Th10 and Th11 of case 1 and Th10 and Th11 of case 2 between the first and second examination This may be explained as follows During the operations the indicators were placed superficially and not deep in the cancellous bone as its structure was estimated to give satisfactory fixation of the indicators However it is probable that the indicators may have moved because of this part of bone being soft during the immediate

postoperative period This explanation is supported by the fact that no such motion was demonstrated during or after the second examination

The possibility that the results would be notably influenced by this small motion between the indicators is however opposed by the fact that the various vertebrae moved in a similar way and also by the fact that these movements were similar to segments without evidence that the indicators had moved relative to each other (Th7–L2 in case 1 Th4–L2 and Th5–L2 in case 2)

The precision in determining rotational angles and translations corresponded to the results obtained previously (OLSSON et coll 1976 b) for suboptimal mutual positions of the indicators An error in rotation angle α about the x and z axes for the reference segment will lead to translation errors d along the z and x axes respectively according to the formula

$$d = 0\,0175\ \alpha\ l$$

where l is the distance (lever arm) between the reference segment and the other one and 0 0175 is the conversion factor from degrees of angle to radians In the actual test the standard errors for the reference segment (L2) were 0 14 and 0 07 for the rotations about the x and z axes respectively which inserted in the formula above with a lever arm of 230 mm give the translation errors 563 and 281 μm along the z and x axes respectively This should be compared to the standard errors obtained directly from the test 526 and 292 μm respectively

A common feature of the three cases was the development of kyphosis (or diminished lordosis) between the first and second supine examination and between the supine and erect position In addition in cases 1 and 2 the scoliosis increased between the first and second supine examinations whereas the scoliosis increased between the examinations in supine and erect standing position in case 1 and decreased in case 2 The scoliosis in case 3 did not increase significantly between the examinations in supine positions Such an increase was found however for Th3–L2 between the supine and erect standing position at the third examination The alterations in the frontal plane (the plane of scoliosis) found for the three cases were thus in agreement with the alterations in the COBB angles as these latter angles were obtained from one supine position during the immediate postoperative period and from one erect standing position one year later The present investigation demonstrated not only higher precision in the measurements but also information about the curvatures developed about the transversal and longitudinal axes A common feature encountered in all three cases was a residual mobility between the vertebrae at the third examination This corresponds to previous reports (HARRINGTON) that the fusion does not become complete until 2 to 4 years postoperatively

In conclusion The effect of scoliosis treatment can be evaluated with high accuracy by the roentgen stereophotogrammetric method used Statements such as 'there are no absolute criteria for the evaluation of end results in the treatment of scoliosis

(MOE & GUSTILO 1964) are no longer valid The only prerequisite is that the indicators must be placed relatively deep in the bone of each vertebra in such positions that they do not all lie on the same straight line or be hidden at the roentgen examination

SUMMARY

Three cases with idiopathic structural scoliosis were examined postoperatively with a roentgen stereophotogrammetric method Curvatures developed in both the frontal and sagittal planes Axial rotation also occurred In addition residual mobility was demonstrated and quantified one year postoperatively

ZUSAMMENFASSUNG

Drei Falle mit idiopathischer struktureller Skoliose wurden postoperativ mit einer Rontgen Stereophotogrammetrischen Methode untersucht Kurvaturen hatten sich sowohl in der frontalen wie der sagittalen Ebene entwickelt Eine axiale Rotation war ebenfalls aufgetreten Zusatzlich wurde eine Rest Beweglichkeit nachgewiesen und ein Jahr postoperativ quantitativ erfasst

RESUME

Trois cas de scoliose idiopathique structurale ont ete examinés apres operation par une methode radiologique steréophotogrammétrique Les courbures se sont developpees dans le plan sagittal et dans le plan frontal il existait aussi une rotation axiale De plus cet examen a mis en evidence une mobilite residuelle qui a ete mesurec un an après l operation

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ROENTGEN STEREOPHOTOGRAMMETRY FOR DETERMINATION OF BONE GROWTH

Comparison with the tetracycline method

A S ARONSON L I HANSSON and G SELVIK

The tetracycline method is the most accurate technique for bone growth measurements in the animal (HANSSON 1967) However the procedure has three major limitations First measurements are only possible after the animals are killed secondly measurements can be made only after special preparatory measures thirdly measurements of the highest quality can be made on only 4 or 5 consecutive days on the same animal

Growth measurements for longer time intervals can be made with different radiologic methods (BRODIN 1955 TAILLARD & MORSCHER 1965) Various types of markers have been used to increase the accuracy of these methods (SARNAT 1968) In previous investigations tantalum markers (pins or balls) were used in the bone for measuring the growth (BJORK 1968 ARONSON et coll 1974) A stereophotogrammetric procedure has been developed (ARONSON et coll 1977 to increase the accuracy of the measurements

In the present report the results of longitudinal growth per day in the tibia as measured by the tetracycline method and the roentgen stereophotogrammetric method are compared

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Material

The material consisted of 42 rabbits from 7 litters 30 days old when the investigation started Eight of them were used in experiments with ball markers in each growth for three different tibial distances were measured i e bi-epiphyseally and proximal epiphysis to proximal and to distal metaphyses respectively In 17 of the remaining 34 rabbits the growth of the bi epiphyseal distance was measured and in 17 the epi metaphyseal distance

Methods

Intraosseous markers of tantalum were introduced to measure leg growth and the increasing distances between these markers were determined by roentgen stereo photogrammetry Simultaneous growth recordings were made with the tetracycline method

Marking Points for measurements on the films were obtained by insertion of markers of tantalum into the tibia Three different types of markers were used large pins 0 50 mm × 1 5 mm small pins 0 37 mm × 1 2 mm and balls 0 50 mm diameter Pins were placed in the right leg only either in the two end epiphyses or in the proximal epi and metaphyses Balls were placed bilaterally in the tibia in both end epiphyses Balls were placed bilaterally in the tibia in both end epiphyses and also in the proximal and distal metaphyses Indicators were inserted with a special instrument percutaneously under fluoroscopic control (ARONSON et coll 1974) The animals were under neuroleptanalgesia Fluanizon 6 and Phentanyl 0 12 mg/kg Hypnorm

Stereophotogrammetry Simultaneous recordings of the rabbits were made with two roentgen tubes about 40 cm apart and about 100 cm above the animal The unanesthetized rabbit was gently fixed in a test cage of glass or Plexiglas whose short ends were open In the cage tantalum indicators of known location were placed in the box lid and bottom and the location of the rabbit indicators was expressed as space co-ordinates defined according to these reference indicators The measurements on the films were made using an autograph (A8 Wild Heerbrugg Switzerland) and the calculation of the space co-ordinates for markers was based on stereometry and performed by computer (HALLERT 1970, SELVIK 1974) The distance between the markers was calculated according to the Pythagorean theorem in three dimensions and growth was estimated from the increase in marker distance The SE in one growth determination is 43 μm for rabbits marked with pins and 30 μm with ball markers (ARONSON et coll 1977)

Tetracycline registration Intravital labelling of the bone growth was made with intravenously injected tetracycline (Terramycin 5 mg/kg) according to the method of HANSSON (1967) Tetracycline given at intervals will produce fluorescent yellow bands clearly visible in 50 to 100 μm thick bone sections All animals were killed one

Table

*Daily longitudinal growth in µm of tibia of rabbits difference between tetracycline and roentgen stereo photogrammetric measurements on the same leg Results mean±SEM µm/day grouped according to to type of markers and duration of experiment after insertion of markers at the start of day 1 Results for pins from right sided measurements results for balls from mean of bilateral measurements E = proximal and E_d = distal epiphyseal markers M = proximal and M_d distal metaphyseal markers * ** *** = degree of significance according to Student s t test*

	Large pins 0 5 mm × 1 5 mm		Small pins 0 37 mm × 1 0 mm		Balls 0 5 mm		
No of animals Day 1 2	7	9	5	8			
Day 21	5				Day 22	8	
Marker localized	E E_d	E-M	E-E_d	E-M	E-E_d	E-M	E_d-M_d
Day 1							
Tetracycline	634	386	587	423			
Rtg	592	336	510	397			
Difference	42±21	50±11	77±6 **	26±10			
Day 2							
Tetracycline	633	367	554	425			
Rtg	582	361	522	407			
Difference	51±20	6±10	32±29	18±14			
Day 21							
Tetracycline	605				504	290	213
Rtg	543				503	292	211
Difference	62±16*				1±16	2±11	2±11

hour after the last injection and the right tibia was prepared for measurements of the distance between the tetracycline bands

Time schedules (1) Short term investigations Four consecutive injections were given with daily intervals first dose 24 hours before second dose simultaneously with the insertion of tantalum markers and the remaining two injections 24 and 48 hours after Recordings with the radiologic method were made after each tetra cycline injection In these 4 series either large or small pins were used and placed either biepiphyseally or epi metaphyseally (2) Long term investigations In this series only 2 injections were given in the beginning and at the end of day 22 (balls) after marker insertion

Compilation of da a The difference in the growth rates obtained from the tetra cycline method and the simultaneously performed stereophotogrammetry was cal culated from daily measurements and expressed in µm/day The mean and the SEM were calculated fo these differences and the significance of the difference was esti mated with Stude-t s t test For experiments with pins the results were based on measurements on one leg only and ball experiments were based on the mean for bilateral measurer ents

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statistically significant in one group After 21 days with large pins the difference was still almost statistically significant whereas in the series with ball markers (22 days) no significant difference was recorded

The difference in growth rates was higher for measurements over the whole length of the leg than over one growth zone for day 1 and 2

Discussion

Two methods for determining bone growth were compared in the present investigation the tetracycline method and roentgen stereophotogrammetry Each has an inherent standard error of measurement the oxytetracycline method 4 to 6 μm/d (HANSSON 1967) the stereophotogrammetric method 30 and 43 μm/d the lower values being for ball markers and the higher for pin markers (ARONSON et coll 1977) The present results show that the two methods give comparable growth rate when measurements are made 3 weeks after the insertion of markers

However if the measurements are made immediately after the insertion on days 1 and 2 a difference exists Thus tetracycline gives larger growth values than the radiologic method The difference may be explained in part by the fact that the two methods do not measure precisely the same distance In addition to the metaphyseal growth measured with both techniques the radiologic method also registers changes in the width of the growth plate

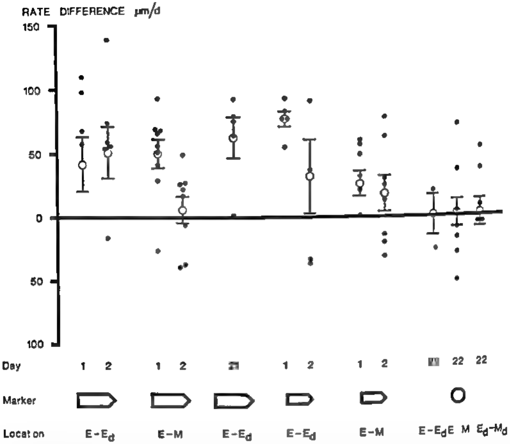
The marking of the leg with tantalum indicators may temporarily inhibit the cell proliferation on the epiphyseal side of the growth zone This will primarily cause a reduction in the width of the growth zone and a decline in the growth rate as measured with the radiologic method Only secondarily after 1 to 2 days will this decreased growth rate affect the metaphyseal growth measured by the tetracycline method (HANSSON 1967)

There is also another cause for the reduced width of the growth zone With increasing age the zone becomes thinner This decrease is only of practical importance at the age of 30 days where it amounts to about 5 μm/d Three weeks later it is only about 1 μm/d (HANSSON 1967)

Apart from these two factors that decrease the growth rate as measured by the radiologic method a third factor increases the difference between the two methods This is the condylar growth which contributes to the growth values of the tetracycline method and not to the radiologic method

The three factors of importance in the short term measurements were expected to be of less importance in the long term measurements In support of this the two growth methods gave similar results for ball markers after 22 days This finding together with the smaller methodologic error and the greater technical simplicity of insertion and measurements for ball markers on the film argues in favour of balls rather than pins as markers

Although less accurate than the tetracycline method this stereophotogrammetric



Difference in daily growth rate in the rabbit tibia between the tetracycline and the stereophotogrammetric methods in different series using different markers and different time intervals after insertion of markers. Individual values ●, mean and ±SEM indicated. E = proximal, E_d = distal epiphyseal markers. M = proximal, M_d = distal metaphyseal markers.

Results

Growth rate. The mean growth rates for the rabbit tibia when markers were placed in the two end epiphyses varied between 504 and 634 µm/d with the tetracycline method and between 503 and 592 µm/d with the radiologic method. Growth rates from the proximal growth zone varied between 213 and 423 µm/d when measured with the tetracycline method and between 211 and 397 µm/d when measured with the radiologic method (Table).

Difference in growth rate measurements. The tetracycline measurements were somewhat greater than the radiologic ones for the first two days after insertion (Table, Figure). The difference varied between 26 and 77 µm/d on the first day after marker insertion; differences were statistically significant in 3 of the 4 groups. On the second day the differences varied between 6 and 51 µm/d and were almost

superieures a l autre methode la difference variant entre 77 et 6 μm/j sur les 2 premiers jours après l insertion des marqueurs et entre 62 et 1 μm/j apres 3 semaines Quand on utilise des balles comme marqueur les 2 methodes sont en concordance 3 semaines apres l insertion. La difference entre les methodes utilisees est due au fait que ces deux méthodes ne mesurent pas la croissance dans des régions exactement identiques

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method with its growth error of about 30 μm for ball markers is far superior to different conventional planimetric radiologic techniques whose accuracy at best is about 1 mm in man (TAILLARD & MORSCHER 1965) and 0 1 to 1 mm in rabbit (HANSSON 1967) Its great advantage over the tetracycline method is that growth is measured without killing the animal as is necessary with the tetracycline method Also the length of the growth period is not limited to 4 or 5 days as is optimum for the latter method These advantages make the method suitable also for clinical use and successful growth measurements have been performed in children with growth disturbances (ARONSON et coll 1975 ARONSON & SELVIK 1976)

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SUMMARY

Two different methods for determination of leg growth the tetracycline method and roentgen stereophotogrammetry were applied simultaneously in 41 young rabbits and compared 1 and 2 and 21 and 22 days after insertion of pins or balls of tantalum as markers The tetracycline method gave slightly higher values than the other method the difference varying between 77 and 6 μm/d on the first 2 days after marker insertion and between 62 and 1 μm/d after 3 weeks When ball markers were used agreement between the two methods was obtained 3 weeks after insertion The difference between the methods used is due to that the two methods did not measure growth in precisely identical regions

ZUSAMMENFASSUNG

Zwei verschiedene Methoden um das Wachstum der Extremitaten zu messen namlich die Tetracyclin Methode und die Rontgen Stereophotogrammetrie wurden gleichzeitig bei 41 jungen Kaninchen verwendet und 1 2 21 und 22 Tagen nach Einsetzen von Nadeln oder Kugeln aus Tantalum als Markore verglichen Die Tetracyclin Methode gab etwas hohere Werte als die andere Methode die Unterschiede variierten zwischen 77 und 6 μm/Tag an den beiden ersten Tagen nach Einsetzen des Markors und zwischen 62 und 1 μm/Tag nach 3 Wochen Wenn Kugelmarkore verwendet wurden wurde eine Übereinstimmung zwischen den beiden Methoden 3 Wochen nach Einsetzen erreicht Der Unterschied zwischen den verwendeten Methoden beruht darauf dass die beiden Methoden den Zuwachs nicht in genau identischen Abschnitten messen

RESUME

Deux méthodes différentes pour déterminer la croissance du membre inférieur la méthode à la tétracycline et la stéréophotogrammétrie radiologique ont été appliquée simultanément à 41 jeunes lapins et comparees 1 et 2 et 21 et 22 jours après insertion d épingles ou de balles en tantale comme marqueurs La méthode à la tétracycline a donné des valeurs un peu

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HIGH-DENSITY FAILURE OF RADIOGRAPHIC FILMS

KJELL SELIN and SVEN REICHMANN

The present report originates in an unpublished observation made by chance during an investigation of the mottle produced by intensifying screens (REICHMANN & HELANDER 1974 a) The mottle was found to be very easily discernible at moderate film densities in certain films being rapidly made invisible when the density was increased This vanishing of the mottle occurred long before the film was overexposed in the common sense of the term Since the mottle constitutes a series of signals from the point of view of the film it was felt that the failure of the film to record or display the unwanted mottle signals was likely to have a counterpart in reduced recording capacity for desired signals as well At least this ought to be the case for small object details of low contrast Since the diagnostic information in many examinations—especially in lung radiography—depends on the demonstration of such signals against a background of high film density the problem was considered to be of clinical importance For this reason the capacity of different films to record a given mottle at different densities was analysed

Experiments I

The initial aim was to find a mottle which was largely unaffected by the total radiation dose This point was important since increased film density is obtained by means of increased exposure in turn leading to decreased quantum fluctuations

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However previously (REICHMANN & HELANDER 1974 a) it has been demonstrated that in screens with inhomogeneous crystal coating the mottle is caused by the crystal clumps rather than by photon fluctuations the resulting mottle being practically unaffected by the radiation dose One such screen (Siemens Rubin) was tested somewhat more accurately in this respect Three films of different sensitivity were exposed the sensitivity thus being changed by a factor 12 5 The most sensitive films were ordinary radiographic films The lowest sensitivity was obtained in an industrial film (Agfa Gevaert Mamoray T3) which was so much more sensitive to the light from the screens than to directly absorbed photons that the latter apparently played an insignificant role The films were exposed to different densities and were developed to the same contrast It was found that the resulting mottle was acceptably independent of the dose level if fairly hard radiation was used A tube potential of 120 kV with an additional filtration of 1 4 mm Cu made the mottle unaffected by the dose changes introduced The constancy of the mottle was estimated by direct ocular inspection This was considered sufficient since in the following experiments the film sensitivity was varied by a factor 3 rather than 12 5

When the recording capacity of a film is tested by means of a screen mottle an important difference in comparison with recording of signals from an object exists In the latter case both screens give rise to the same signals However the mottle produced by the two screens is the sum of two different mottles and so the film in fact records two different images one from each screen In any case a certain amount of light always passes from one screen through the adjacent emulsion and the film base exposing the opposite emulsion as well This exposure is called cross over exposure Due to scattering and spreading out of the light the cross over image becomes unsharp Thus low image frequencies are left rather unaffected high frequencies being blurred The cross-over image is added to the one coming from the adjacent screen thus reducing the visibility of the high image frequencies When the recording of screen mottle is investigated the cross over exposure tends to reduce the amplitude of all image frequencies coming from the adjacent screen since the images produced by the two screens are not identical Furthermore they consist mainly of high image frequencies

Thus a suitable screen being available the examination could not only consist in exposing a number of films to different densities The influence of the cross over exposure had to be measurable in all film types and densities Roll machine development being desirable in order to make the test realistic the cross-over exposure could not be analysed separately since development characteristics might change in the meantime For this reason each film was intended to demonstrate both the composite effects of two screens with two emulsions and the influence of the cross over exposure as well The following mode of exposure and development was adopted Exposure was made on double-coated film using two screens However two thin sheets of black paper screened off the light from part of the front screen and back screen respectively so that three different areas of exposure were obtained front

Table 1

The different types of exposure and development performed for each film recording the structure mottle from a pair of Rubin screens The exposure produced by the front screen to the front emulsion is represented by the figure 1 Its cross-over exposure to the back emulsion is called c-o (1) For the back screen the figure 2 is used correspondingly In the experiments 2 was 160 per cent of 1

Exposure	Development		
	Both emulsions	Front emulsion	Back emulsion
Both screens	1+c-o (2)	1+c-o (2)	
	2+c-o (1)		2+c-o (1)
Front screen	1	1	
	c-o (1)		c-o (1)
Back screen	2		2
	c-o (2)	c-o (2)	

screen only back screen only and both screens These three areas formed three parallel fields Before processing two strips of tape were glued one onto each emulsion in a direction crossing these fields without covering each other After processing the tapes were removed and the film was sent through fixing rinsing and drying a second time In this way three zones of development were obtained front emulsion only back emulsion only and both emulsions The differently exposed and developed film areas are represented diagrammatically in Table 1 It should be noted that the same structural appearance was obtained in each film

For each film type a series of 10 sheets of film was exposed the nominal exposure dose being increased 1 3 times for each step The exposure was changed by increasing the exposure time the tube potential and current settings remaining unchanged However it was found that the intervals between different exposure times were not constant and so a completely smooth characteristic curve could not be obtained from the image density of the different films against nominal exposure data Separate sensitometry for two emulsions exposed by two screens was therefore performed These sensitometry films were developed together with the films to be evaluated

Five commercially available radiographic films were tested Four of them were black and white the fifth being a monochrome colour film namely Agfa Gevaert Medichrome This film was processed in its own chemicals as recommended by the manufacturer Only one of the black and white films (not the one yielding the best image recording) was processed in accordance with the manufacturer s recommendations all films being processed in the same machine Since the intention was to estimate principles of image recording at high densities rather than making a comparison between different brands of film the black and white films will be mentioned only in terms of a code A subsequent test of development conditions (time and tempera

Table 2

The sensitivities and cross-over exposure factors of the films tested. Film (E) is the Medichrome, the other films being black-and-white. The cross-over factor is expressed in per cent of the total exposure which derives from the cross-over exposure

Film	Approx. rel. sensitivity	Cross-over
(A)	100	30
(B)	100	30
(C)	100	37
(D)	50	40
(E)	30	30

ture for optimum recording of weak signals) revealed that the results presented in this communication cannot be due to unfavourable development conditions in general (SELIN & REICHMANN, to be published). The films are listed together with their approximate sensitivities in Table 2. For one film (D) two series of exposures were made. In one of them the general exposure level was somewhat higher, the development temperature being lowered to a corresponding degree, giving a softer recording in this series.

Densitometry was carried out for the different areas of all films. The amount of cross-over exposure was calculated from these data in conjunction with the sensitometric characteristic curve. The relative light outputs from the screens were also determined. The back screen was found to emit 1.6 times more light than the front screen.

The recording of the mottle was evaluated visually. Two slightly different modes of inspection were used: direct inspection and inspection after magnification and increase of contrast. At direct inspection different light sources were used, differing in light intensity. For the highest film densities a narrow beam of light from a projector (150 W halogen lamp) gave satisfactory illumination for the black and white films, which give an intense scattering of light at high densities. The Medichrome film is free from all types of scattering, which means that it requires diffuse light for good perception of image detail. This was difficult to provide for high densities. The glow lamp filament of the projector lamp was visible through the Medichrome film, making this light source useless for this film. This means that evaluation of the image at high densities was difficult, especially when the film was inspected through a colour filter for contrast increase. Magnified copies on sheet film were produced from such images as were considered to be especially interesting. The intention was to increase the size and contrast of the image details so that they would be safely above the thresholds of vision. Furthermore, all copies displayed similar density and so the light source problem could be eliminated even for the high-density Medichrome film. Magnification was carried out in a photographic enlarger with good optical properties, the magnification factor being 6.

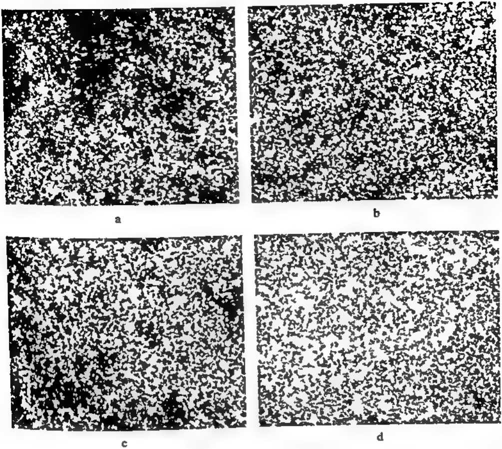
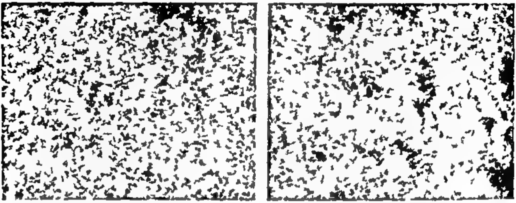


Fig 1 A screen mottle structure recorded by two different films at different densities Film (A) at density 0 97 (a) and 2 19 (b) is compared with film (B) at 1 04 (c) and 1 80 (d) Both film emulsions were exposed and developed In (a) (b) and (c) a spottedness is seen consisting of dark and bright areas of varying size representing the magnified (×32) screen mottle In (d) no mottle is seen only the film graininess Film A retains its recording capacity at higher densities than B although the mottle is somewhat less distinctly depicted in (b) than in (a)

Results

At direct inspection all films displayed the same type of recording The mottle was best visible in images having only moderate background density In all films the optimum appeared to coincide with densities ranging between 0 9 and 1 3 The disappearance of the mottle displayed significant differences In film A optimum reproduction was considered to occur up to density 1 5 Above that value the mottle image slowly deteriorated with increasing density However the mottle was still discernible at 2 4 Film B having the same sensitivity as A gave good image quality up to 1 3 At 1 8 the image had completely disappeared These two films represented the two extremes The other films appeared to have reproduction qualities somewhwere in between



a b

Fig. 2 The same screen mottle as in Fig 1 recorded by a Medichrome film at D = 0 91 (a) and D = 2.08 (b) The film graininess is low and the difference in recording is insignificant Magnification × 32

The depiction properties described were found out by direct inspection of the films However the same results were obtained for black and white films after magnification and increase of contrast (Fig 1) For the Medichrome film a certain discrepancy between direct observation and observation after magnification and contrast increase was noted At density 2 3 the mottle was considered invisible on direct inspection the direct visibility being reduced at 2 1 as compared with 0 9 However the magnified images of the last two densities (Fig 2) displayed surprisingly small differences

Differences between films of the kind described are certainly interesting in themselves A film giving good reproduction of small details of low contrast even at high densities is to be preferred in many types of examination whatever the underlying mechanism may be Still it seemed to be of interest to correlate these findings with certain other parameters of the films namely contrast as measured by means of a conventional densitometer and cross over exposure The cross over exposure was found to vary between the films (cf Table 2) However the films having a high cross over factor did not turn out to have the lowest recording capacity at high densities Moreover the two extremes in recording at high densities—films A and B—had the same cross over exposure This is not to say that the cross over exposure was found to be insignificant On the contrary the addition of the light having passed through the film base tended to wipe out the image details especially at high densities Since evidently this extinction might be a consequence of impaired contrast the latter factor must be considered as well However it may be stated even at this point that the cross over exposure in itself cannot have been the only or even the most important factor explaining the recording differences between the different films

The influence of the contrast factor was determined in one film type at a time Since the characteristic curve of all films was more or less S-shaped the same in

clination of the curve could be obtained for two different densities one above and one below the density giving maximum contrast The aim was to find two such corresponding densities in each film and compare the recordings of the mottle However in this experiment the influence of the development had to be considered very carefully Due to the experimental conditions the two corresponding densities always appeared in different films and although the films were developed in the same machine one shortly after the other certain temperature variations might be expected to occur in the meantime A conventional Pakorol processing machine was used allowing variations in the temperature of the developer amounting to 0 5 C However the contrast factor could be determined for each film without any reference to other films in the same series due to the different speeds of the two screens the back screen emitting 1 8 times more light than the front screen From the different densities appearing in film areas exposed to each one of the screens with and without the cross over exposure a contrast index could be established for the film areas to be compared as regards their recording capacity at high and low density respectively This contrast index was found to give a smoothly changing function in accordance with the characteristic curve

In the way mentioned two films of each film type were compared after magnification and increase of contrast Since the two screens displayed a speed difference only the front emulsion was inspected the corresponding back emulsion remaining undeveloped Film areas with and without cross over exposure were inspected The films were chosen so as to give the same contrast in the area where the front screen exposure and the cross over exposure cooperated The latter exposure had the same properties as diffuse light without any signals The frequency spectrum of the mottle produced by the back screen lay at high frequencies which were filtered away when the light passed through the film base Thus the cross over exposure in this experiment imitated the influence of any type of diffusely scattered energy such as secondary radiation

The same structure appeared in all the film types Again however the Medichrome film appeared to lose comparatively less of its recording capacity than did the black and white films The images obtained from film A appear in Fig 3 In (a) and (c) is seen the mottle image of the different exposures when the cross over exposure has not been added The contrast was higher in (c) than in (a) When the cross over exposure was added to (a) the density and contrast increased (b) The mottle was visible to approximately the same degree in (b) as in (a) despite the addition of diffuse light However when the same amount of diffuse light was added to (c) the mottle structure disappeared altogether (d) Still the contrasts of (b) and (d) were identical or rather insignificantly higher in (d) This finding must imply that the gross contrast as measured by means of an ordinary densitometer could not be the factor underlying the failure of the film to record weak signals of high frequency at high film densities

Another important observation may be made on the basis of Fig 3 At low den

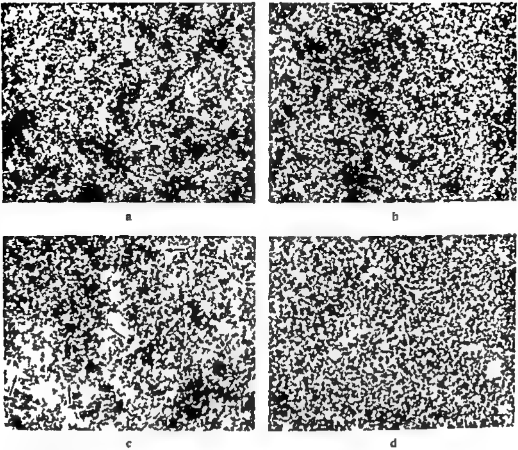


Fig 3 The same screen mottle as in Fig 1 recorded by the front emulsion of film A (×32) In (a) and (b) the same exposure was used In (a) light came only from the front screen which gave rise to the mottle the density being 0 41 In (b) additional light without mottle had passed through the film base from the back screen as well density 0 71 Corresponding recordings involving a higher dose are presented in (c) and (d) the densities being 1 04 and 1 43 respectively The film contrast is slightly higher in (d) than in (b) being highest in (c) and lowest in (a) Still the recording of very small spots is better in (a) and (b) as compared with (c) and (d) respectively With increasing density the smallest spots of the mottle tend to unite into larger areas where no further recording of mottle signals appears to take place (→ in c compare the numerous small spots in a) The non recording final stage of (d) arises from a confluence of the large spots in (c) The addition of cross-over light to (a) made little harm to the recording (b) while the same proportion of cross over light added to (c) made the whole mottle structure invisible despite higher film contrast in (d) than in (b)

sities the mottle appeared in every point of the image (a) but with increasing density (b and c) the mottle appeared to have a somewhat coarser structure This suggests that the highest signal frequencies had not been recorded Moreover small empty areas of high density where no signals were visible began to appear (c) so that the signals were evidently left unrecorded by the film in these places The total failure of the film to record the signals in (d) appeared to be due to spreading out and over lapping of these empty areas

Discussion I

NELSON (1949) as well as MATTSSON (1955) in summarizing the earlier investigations on quality aspects of radiographic films conclude that only two parameters appear to be of importance namely sensitivity and contrast as expressed by the characteristic curve This view still appears to be generally accepted The cross over exposure may be added to the list although it is rather seldom discussed Since the first mentioned parameters are easy to measure and to influence—contrast for example may be corrected within wide limits by means of changed development—the film is often disregarded by investigators trying to establish optimum working conditions in radiographic systems (cf GAJEWSKI & KUHN 1972 PFEILER & KUHN 1973) Another reason why the film is omitted in most discussions of image quality also exists During the 1960s the modulation transfer function (MTF) became very popular in descriptions of the final unsharpness of the image In that connection it was noted that films exposed to direct roentgen radiation displayed an MTF of considerable overcapacity as compared with the rest of the system notably the screens Thus the film was considered to be such a strong link in the chain as to be rather uninteresting (MORGAN et coll 1964 ROSSMANN & LUBBERTS 1966 HAUS & ROSSMANN 1973) Curiously enough the MTF of the film was determined in a way which cannot incorporate the cross over exposure for visible light and the subsequent scattering which is the contribution of the film to the final unsharpness of the image It appears that the presumed sharpness overcapacity of the film still has to be demonstrated if it exists at all

More than many other authors ROSSMANN (1964) stressed the fact that the invisibility of detail may be a question of a bad signal/noise ratio rather than unsharpness If weak signals are to appear in the image the noise must be kept low In the search for noise sources the granularity of the film has been considered In full size radiography it was found to be insignificant as compared with the quantum mottle (ROSSMANN 1963 FRIEDELL & GREGG 1965 DE BELDER 1972) and so again overcapacity of the film appeared to be at hand Only in cineradiography with high sensitivity 35 mm films could influence of the graininess be seen to impair image quality (JOTTEN 1966)

In spite of these apparent overcapacities direct measurements of film performance have given evidence to the effect that the film may still be a weak link in the chain The measuring technique in question implies determination of the perceptibility curve (DE BELDER & BOLLEN 1971) defined in the following way Different weak signals are recorded in a film at different densities (corresponding to the exposures E) and psychometrically the lower limit of signal perceptibility (corresponding to the exposure interval Δ log E) is determined at these densities The curve showing $1/\Delta$ log E against log E is called the perceptibility curve and obviously maximum perceptibility occurs when the threshold signal intensity is minimal This perceptibility curve was published for the Agfa Gevaert Curix RP 1 by TALPE (1971) A maximum

was seen at the density 1 3 the curve falling steeply for densities above that value This reduction of perceptibility mainly took place within a density range that would not usually have been regarded as overexposure These data point in the same direction as the present ones For this impairment of perceptibility in densities which are high but not generally regarded as overexposure it is suggested to introduce the term high density failure

In psychometric tests the error of different modes of inspection must be considered A well known obstacle appears in high densities since too small an amount of light passes into the eyes Furthermore if stray light passes outside the high density images inspection will be markedly impaired These problems were analysed by KANAMORI (1966) who found certain density levels to be optimum However this cannot be the whole explanation of the high density failure found in the present investigation since not even copying to a constant density level revealed that there were any signals present in certain high density films (Fig 3 d) Similarly the present experiments gave evidence that neither contrast in the sense of the characteristic curve sensitivity nor cross over exposure could be the crucial factor There must be another important film parameter involved

In a previous investigation on how secondary radiation impairs image quality certain data were obtained suggesting that the total number of independently reacting film grains per unit area of a film may be more important than commonly assumed (SELIN et coll 1975) Each grain forms a receptor with two modes of carrying information The grain may be developed into black silver (or blue dye in the Medichrome film) or the silver halide may be removed in the fixing bath Both presence and absence of a given grain imply information Since the individual grain only carries one bit of information and the grain number is limited it must also be expected that the total information storage capacity is limited If a given signal pattern is exposed on a film in such a way as to produce images of identical contrast (straight characteristic curve) but increasing density then an increasing number of the grains would be wasted in creating the inert background density Fewer and fewer grains would then be available for the recording of the signals This would give rise to a steady decrease in perceptibility function above an optimum density situated in the lower part of the straight part of the characteristic curve

This theory may appear somewhat hard to accept The only report indicating that the film grains of radiographic films exposed by light may be of real importance was published by TAYLOR (1974) The objection is often raised that there are such enormous numbers of grains per unit area that a very safe overcapacity should again be at hand However a grain which is made developable mainly by light photons representing scattered energy constitutes a loss From the report by ROSE (1973) it even appears likely that the presence of these useless silver grains will reduce the visibility of the signal grains proper so that a higher amount of the latter is required than would be necessary without scattered energy (cf SELIN et coll) Many sources of scatter exist in radiographic systems Beside the off focus radiation and secondary

radiation from the patient there are considerable sources of scatter within the recording medium itself The screens give rise to secondary radiation mainly in the form of fluorescence photons and high-energy electrons (STEVELS 1975) This scatter has been found to raise the sensitivity of the recording medium (RIEHL & ZIMMER 1937 MEILER 1974) which means that this factor alone will reduce the number of useful film grains considerably In screen film radiography light photons are scattered to a considerable degree This occurs inside the fluorescent layer as well as in the film the latter scattering being represented mainly by cross over exposure For signals of high frequency these scattering processes may grossly impair the contrast as is well known from MTF experiences This means that substantial parts of the energy that carries the signals are scattered

In the primary radiation there are always roentgen photons which have not been scattered but which will still consume relatively large amounts of silver halide grains without giving optimum information in exchange This is due to the continuous spectral distribution of the primary radiation which reaches the intensifying screens Especially for certain types of absorption differences such as calcium or iodine as opposed to soft tissues the signals are not evenly distributed over the hole spectral range of the primary radiation Instead the signals are found mainly in the lower photon energy ranges i e at long wavelengths of the radiation The high-energy photons of the primary spectrum then give rise to a blackening of the film without carrying by far the same amount of information as the low-energy photons of the spectrum This type of silver grain consumption may be expected to be marked if the screens are sensitive to high-energy photons rather than to photons of low energy According to STEVELS different screen substances differ substantially in spectral sensitivity

One further point has to be considered as to the number of grains It concerns the number of silver grains required to accomplish a certain density increase when the background density is low or high respectively The problem may be illustrated in a theoretical example A film with one emulsion is assumed in which the silver halide grains form one uniform layer The characteristic curve is absolutely straight between 0 8 and 2 5 This means that a given signal which raises the density from 1 0 to 1 1 will raise the background density of 2 0 up to 2 1 When the background density is 1 0 10 per cent of the incident light passes through the film This means that 90 per cent of the film area is covered with silver When the background density is 2 0 the area covered with silver is 99 per cent Since the film at the site of the signal has a density of 1 1 and 2 1 respectively 92 per cent of the first is covered with silver the corresponding value for the second being 99 2 per cent Thus when the background density is 1 0 the signal in question will cover 2 per cent of the whole surface with silver However when the background density is 2 0 the same signal will correspondingly cover 0 2 per cent of the whole area If all the grains had the same size this would imply that the signal is recorded by 10 times as many grains at the lower density than at the higher However the conditions assumed here never exist The

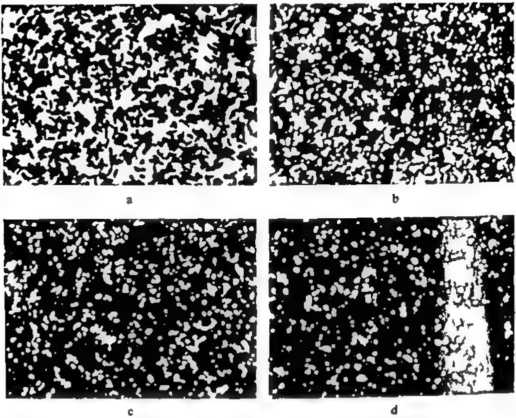


Fig 4 Photomicrographs (620 of the films presented in Fig 3) The density steps are (a) to (b) 0 30 (b) to (c) 0 33 and (c) to (d) 0 39 The step of 0 30 against the density 0 21 of (a) was represented by a much larger number of grains than the step of 0 39 against the density 1 04 of (c) A given output signal from the film as indicated by a constant density increase is thus constituted by a decreasing number of silver grains when the background density increases

characteristic curve is not exactly straight there are two emulsions with several layers of grains in each and the grains being precipitated at high densities are smaller than those forming a low density image Still it appears plausible that a given signal is recorded by a relatively large number of grains if the background density is low even if the proportions may not be so impressive as those arrived at theoretically

The result in the foregoing led to the desirability of further data first about the microscopic distribution of grains at different densities and secondly about the influence of different types of development

Experiments II

The grain distribution of the black and white films was analysed with regard to image density by means of microscopy and photomicrography The four images in Fig 3 appear as photomicrographs in Fig 4 These four density levels in one emul

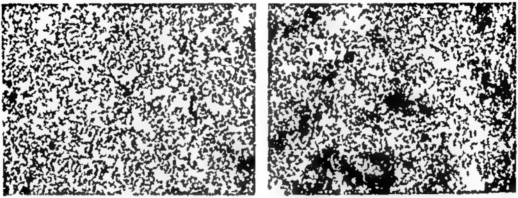
sion represent three fairly similar density steps a to b=0 30 b to c=0 33 c to d=0 39 When the images are inspected the following should be kept in mind If any further blackening is to be added to a given density this must be done by means of deposition of silver in silver free areas Thus the bright areas reflect the capacity of the films to record further information It is evident that the change in the distribution and extension of the bright areas is considerably greater for the density step of 0 0 for the background blackening of 0 41 (compare a and b) than for the step of 0 39 against the background of 1 04 (compare c and d) The step between (b) and (c) is apparently somewhere in between The same was observed throughout the material the bright areas changed to a greater degree for a certain increase in density when the background density was low than when it was high

Another observation is readily made in Fig 4 In (c) and (d) many grains have accumulated into large clumps These are to be regarded as over exposed areas of the film for even if more silver could be precipitated in these parts as a consequence of further exposure this would not affect the transmission characteristics of light It cannot be more black than black This type of aggregation began to appear at double emulsion densities of about 1 5 in the black and white films i e at approximately the density where the reproduction capacity appeared to pass into the zone of commencing high density failure

Together these two observations justify the following conclusion When a signal having a density of 0 1 is placed on top of a background density of 1 0 the discriminating grains are more numerous and more evenly distributed than is the case when the same signal stands out against the background of 2 0

To evaluate the influence of development the type of experiment described under the heading Experiments I was repeated for film B designed for 90 s development The aim was to find out whether a longer development at a lower temperature of the developer would reduce the high density failure so that the signal pattern would be visible at densities where it would otherwise have been invisible The 90 s process was the one recommended by the manufacturer and the chemicals were seasoned for the film type in question The process time was increased to 2 5 min and the temperature was lowered from 28 C to 25 5 C In this way the sensitivity of the film increased slightly as did the contrast especially at high densities Two series were made one for each processing alternative This means that for the 90 s process two complete series of films were obtained for the same film on different occasions so that the reproducibility of the method could be tested This was found to be so good that the difference between films referred to earlier cannot be ascribed to defects of the testing When the two series in the present experiment were compared a clear shift of the high density failure towards higher densities was observed After a process time of 90 s the signal structure had disappeared at 1 8 With 2 5 min of processing the structure was still visible at 2 0

The difference between the two modes of processing was determined as follows One film (type B) was exposed in the cassette by means of a very high radiation dose



a b

Fig 5 Magnified (= 32) recording of a simulated mottle in film B Development 90 s in (a) and 2 5 min in (b) Density 1 70 in both cases The temperature of the developer was adjusted to give the same densitometric contrast in both films at this density Still the signals are more clearly recorded in (b)

to obtain maximum blackening after development Only one emulsion was developed to make densitometry easier and safer The densitometry after a process time of 90 s was 1 39 while after 2 5 min it was 1 65 For double emulsions this would correspond to about 2 7 and 3 2 respectively

In the last experiment the contrast factor could not be kept constant between the two series of films over the whole density range Even if the other experiments of this type indicate that contrast may not be crucial for the high density failure it still seemed desirable to estimate the influence of development under more strictly defined contrast conditions Furthermore it seemed of interest to find out whether the differences in image quality thus introduced would be detectable to observers unfamiliar with the scope of the present investigation The same film (B) was used and two images were produced with exactly the same contrast at a density of 1 7 using process times of 90 s and 2 5 min To facilitate inspection for the untrained observer the signal was obtained in another way than before Screens of the brand Kodak X omatic Fine were used giving a virtually noise free image The signals were obtained from 5 coarse sandpapers placed on top of each other the papers being exposed at 45 kV An aluminium step wedge included in the view field displayed the contrast function The two images at density 1 7 were shown to 8 observers 4 of them being radiologists Inspection was performed with an ordinary light box all stray light being screened off The observers were told to find out whether the two images displayed the granular structure in the same way or not One of the untrained observers could not see any difference between the two modes of development The others preferred the image developed for 2 5 min None of them preferred the image developed for 90 s Those preferring the 2 5 min image often gave a reason for their impression saying that this image was more distinct brilliant or clear Correspondingly the 90-s image was considered to be more greyish The two images were magnified in the same way as the other films the final images are demonstrated in Fig 5

Discussion II

The photographic process of clinical screen film radiography differs from conventional photography in several ways The film sensitivity is high as well as the gamma value The development is rather extreme when compared with most other branches of photography Very energetic developers are used at unusually high temperature and for short process times These circumstances in conjunction with the extraordinary levels of scattered photon energy make radiographic recording very special and experiences from other branches of photography may not be routinely applied In conventional photography the graininess/granularity is of high significance The grain number per unit area is seldom discussed However the present findings suggest that this factor is of importance in radiography

Fine object details of low contrast are better demonstrated at low densities than at high even if the gamma value for the densities in question is kept constant Non appearance of signals in radiographic films is usually ascribed either to unsharpness or to an unfavourable signal/noise ratio From the theory outlined below it appears that the high density failure is a peculiar variant of the latter mechanism

A signal appearing against a background of high density seems to manifest itself by means of a relatively low number of grains unevenly distributed in the film In fact overexposure is a process which sets in gradually In its conventional sense the term is applied when the gamma value drops rather abruptly at a high density However this only implies that the reaction capacity of the film has reached a definitive limit Long before this occurs the aggregation of silver grains in many places have made the film overexposed in these areas The film as a whole may still react but only between the aggregations since in the latter the film is already impermeable to light Thus when aggregations have appeared to such a high degree that the film can react to further exposure only in scattered areas which may be called a relative overexposure in contrast to the absolute overexposure at the top of the characteristic curve In this density region of relative overexposure the gamma value can be maintained at the same level as in the region of ideal depiction

The high density failure is no absolute entity Instead the impairment of image quality is highly dependent on the type of signal involved Conventional densitometers have a measuring area with a diameter of several millimetres Thus the signals giving rise to the characteristic curve may be said to represent a frequency of about 1/2 cycle per millimetre or even lower For such low frequencies the characteristic curve may be expected to describe the image quality of the film However most diagnostic signals need good reproduction of higher frequencies When the frequencies are high and the image density as well the overexposed microareas of the film will make the areas with a remaining reaction capacity so small and scattered that reproduction cannot yield the quality suggested by the characteristic curve One way to obtain visible reproduction of high frequencies even in dense images seems to be the use of high signal amplitudes In almost every case where

quality is discussed the reproduction of high contrast objects such as Funck grids or other lead bars predominates in the testing procedure in a completely unjustified way Human beings do not consist of lead bars they also produce far more scattered radiation The indiscriminate use of these heavy metal test objects in situations where they are unjustified has given rise to the myth of the overcapacity of the film since for this type of object the screens constitute the weak link in the chain more often than the film If weak signals are used for the testing of screens and films both components will certainly be found to contribute to impairment of image quality

One aspect of the problem to avoid high density failure has been tested in the present investigation the development Different regimes giving identical contrast in the sense of the characteristic curve may give different high density failures Apparently the choice of film also plays a great role This may be a reflection of differences in grain size distribution so that a film with insignificant failure at high densities may precipitate more grains per unit area even at a high density for a given weak signal than is the case for a film with a marked recording failure In this connection the principles underlying the manufacturing of the Medichrome film may be worth considering This film has silver halide grains whose size is about 60 per cent of the grain size of Agfa Gevaert Curix RP 1 (data from Agfa Gevaert) These small grains give rise to little aggregation as may be observed in the microscope Furthermore the grains are substituted for transparent blue dye so that 90 per cent of the original silver is removed from the emulsion in the fixer This means that even if colour grains are superimposed they will not lose their informative capacity for the simple reason that they are transparent therefore the aggregation becomes more harmless The small silver halide grains make it possible to obtain many grains from a small absolute amount of silver—the Medichrome film contains only 7 4 g m The transparency of the colour grains and the large number of grains are supposed to explain the good recording of weak signals in this film (DE BELDER & BOLLEN 1971 REICHMANN & HELANDER 1974 b) Despite the properties just mentioned the film has a high density failure However the present results have shown this failure to be largely of an apparent nature More information seems to be recorded at moderately high densities than may be perceived by the eye A contrast increase as accomplished by the *yellow orange* and *red filters* brings out part of this *concealed information* (DE BELDER & BOLLEN REICHMANN & HELANDER 1974 b) However at the same time the density increases markedly which means that very high intensities of red light are necessary to make visible weak signals against a high background density in the Medichrome film Due to the non scattering properties of the colour emulsion this high intensity light source should give rise to diffuse light

SUMMARY

The recording of weak signals of high spatial frequency emanating from intensifying screens has been analysed in different films at varying densities Even if the gamma value is kept constant over a wide range of densities the recording of these signals is impaired at

high densities above a certain optimum density coinciding with the lower part of the straight part of the characteristic curve The recording of these signals appears to be related to the number of silv r halide grains per unit area available for signal recording rather than to the contrast as represented by the gamma value When the density of the image is increased more grains are precipitated in creating the background density leaving a smaller number of grains unaffected for the signals added on top of the background If the signal frequency is high and the amplitude is low the remaining grains appear to become too few and too scattered for a proper recording so that the signal cannot appear in the image Since this occurs at densities where the film is not usually considered to be overexposed the phe nomenon is called high density failure Different films may display great differences in high density failure even if the sensitivity is the same

ZUSAMMENFASSUNG

Die Registrierung der schwachen Signale von hoher raumlicher Frequenz die von Verstarker schirmen ausgehen wurde bei verschiedenen Filmen von verschiedener Dichte analysiert Auch wenn der Gammawert uber einen weiten Bereich von Dichten konstant g halten wird ist die Registrierung dieser Signale bei hohen Dichten uber einer bestimmten optimalen Dichte verschlechtert sie fallt mit dem kleineren Bereich des geraden Bereichs der charak teristischen Kurve zusammen Die Registrierung von dies n Signalen scheint eher zur Anzahl von Silberhalidkornern per Flacheneinheit die zur Registrierung von Signalen zu Verfuhrung steht relatiert zu sein als zum Kontrast der durch den Gammawert reprasen tiert wird Wenn die Dichte des Bildes ansteigt werden mehr Korner ausgefallt die die Dichte des Hintergrunds bilden wobei eine geringe Zahl von unbeeinflussten Kornern fur di Signale ubrig bleiben die auf den Gipfel des Hintergrunds hinzukommen Wenn die Signalfrequenz hoch und die Amplitude niedrig ist sind die ubrigbleibenden Korner zu gering und zu verstreut fur eine Registrierung o dass das Signal nicht auf dem Bild mehr erscheinen kann Da das bei Dichten der Fall ist bei welchen der Film gewohnlicherweise nicht als uberexponiert erscheint wird dieses Phanomen als Hoch dichte Fehler bezeichnet Verschiedene Filme konnen grosse Unterschiede im Hoch-dichte Fehler aufweis n auch wenn die Empfindlichkeit die gleiche ist

RESUME

L enregistrement de signaux faibles de haute frequence spatiale provenant d ecrans ren forçateurs a ete analysee sur différents films a des densites variables Meme si on maintient la valeur du gamma constante sur une large gamme de densites l enregistrement de ces signaux est perturbe à de fortes densites au dessus d une certaine densite optimale qui coin cide avec la partie inferieure de la partie rectiligne de la courbe caracteristique L enregistre ment de ces signaux parait etre en relation avec le nombre de grains d halogenure d argent par unite de surface disponibles pour l enregistrement du signal plutot qu avec le contraste represente par la valeur du gamma Quand la densite de l image augmente un plus grand nombre de grains est precipité pour creer la densite du fond laissant un plus petit nombre de grains intacts pour les signaux qui s ajoutent sur le fond Si la frequence du signal est élevee et si son amplitude est faible les grains restants sont trop peu nombreux et trop dis persés pour un e egistrement convenable de sorte que le signal ne peut apparaitre sur l image Etant do ne que ceci se produit a des densites ou on ne considere pas habituelle ment que le film st surexpose ce phenomene est appele insuffisance de haute densite Des films differents p uvent presenter de gr de difference d insuffisance de haute densite meme si leur sensibilit st la meme

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FROM THE DEPARTMENTS OF ORTHOPAEDIC SURGERY T 3 AND DIAGNOSTIC RADIOLOGY
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RADIOLOGIC TECHNIQUE FOR MEASURING INSTABILITY IN THE KNEE JOINT

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A method for the exact measurement of ligament stability in the knee joint would be of clinical importance not only for the diagnosis but also for assessing the thera peutic results after conservative or surgical treatment of ligament ruptures

Instruments for measuring ligament stability have been constructed and used successfully on knee joint specimens (BRANTIGAN & VOSHELL 1941 HALLÉN & LINDAHL 1965 a b) but it has proved considerably more difficult to obtain accurate measure ments in living subjects This is because in specimens the measuring instruments can be fastened directly to the bone while in vivo soft tissues will be interposed KENNEDY & FOWLER (1971) designed an electrically operated hydraulic machine for assessing medial and anterior instability in the knee joint under the influence of well defined forces during radiography

The advantage of a radiologic measuring method over those employing external measurement with an instrument placed on the lower limb is that direct images are obtained of the distance between the bones of the joint as a measure of the magnitude of instability As the ligaments join bone to bone the variation in this distance depends directly upon the state of the ligaments provided that other sources of in stability (e g bone or cartilage destruction) are not present The incalculable inaccuracy of the measurement due to shifts in soft tissues is avoided

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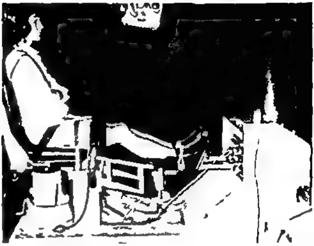

Fig. 1 The gonylaxometer lateral view Patient in position for measuring medial or lateral instability Cassette holder in position under the patient s knee

An apparatus has been designed according to the principles of KENNEDY & FOWLER The method of measurement on the films has been revised in an endeavour to create an exact and reproducible technique for determining not only medial and anterior but also lateral and posterior instability in the knee joint

As the gonylaxometer an apparatus for application of stress on the knee ligaments by well-defined hydraulic forces in different directions is described in detail elsewhere (JACOBSEN 1976) only its leading principles will be mentioned here Well defined radiologic landmarks of the knee joint must be used for the measuring on the films Despite fixation of the patient s feet some rotation occurs during application of traction or pressure to the joint Thus the method also requires measurements for each pair of condyles prompting a detailed description of the radiologic technique

Measuring apparatus The gonylaxometer (Fig 1) is built up over a horizontal steel trolley which supports a seat for the patient a control panel containing the hydraulic mechanism measuring and operating apparatus as well as slides and pistons to act upon the patient s lower limbs The seat floor and slides are furnished with fasteners

To obtain lateral views in 90 flexion a cassette holder (24 cm × 30 cm) is placed sagittally between the knees For exposures during adduction and abduction a cassette holder (30 cm × 40 cm) is placed beneath the knees (Fig 1)

Radiologic procedure

A ceiling suspended roentgen tube (telescope suspension) was used with stationary grid cassettes at a film focus distance of 1 m The tilt of the tube was indicated on a scale The tube potential was about 50 kV exposure times 0 16 to 0 20 s (about 60 m As) and the magnification was 1 1

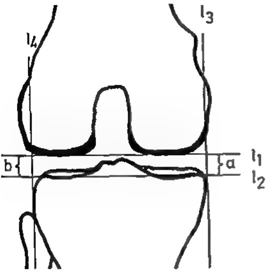

Fig 2 Construction of measuring points on the a p film (no force acting on the joint)

Measurements are made in two positions (a) Abduction and adduction laxity (medial and lateral instability respectively) With the knee joints flexed 20 a p views of both knees are obtained simultaneously This initial position in which the knees are unloaded and relaxed and the feet rotated 5 externally in relation to the normal anatomic position is called neutral position 160 (b) Anteroposterior instability The knee joints are flexed 90 and a lateral view of each knee is exposed This position with the foot resting on the floor of the apparatus and the apex of the patella tibial tuberosity and 2nd metatarsal bone in the vertical plane through the tibial axis is called neutral position 90 The 2nd metatarsal bone will point forward in the direction of traction

The subject is placed in neutral position 160 as indicated by a goniometer measuring from the greater trochanter of the femur to the lateral malleolus over the lateral femoral epicondyle (vertex) The large cassette holder which is angulated 10 from the horizontal plane is mounted The thigh and lower leg then form a flat isosceles triangle with a sagittal line in the plane of the cassette as the baseline The top angle is 160 the base angles each 10 The tube is centered midway between the knees and the central ray is at a right angle to the baseline A film is exposed in the resting position while the limbs strapped to the seat and foot rest are unloaded and placed so that the subject feels the legs relaxed Thereafter another two films are exposed while first abducting and then adducting both lower legs each being subjected to a force of normally 9 N

After adjustment to neutral position 90 a lateral view is exposed of the unloaded knee joint The tube is adjusted at right angles to the sagittally placed film cassette holder midway between the knees The direction of the beam is lateromedial The lateral femoral epicondyle is marked with Indian ink and the central ray is directed

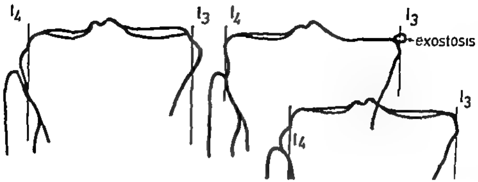

Fig 3 Varying shapes of the tibial joint sockets with different examples of adjustment of measuring lines

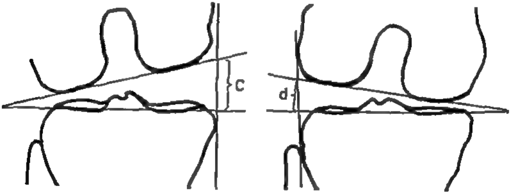

Fig 4 Measuring technique on the a p view after application of abducting and adducting forces

at the mark During p a traction and later during a p pressure of the lower leg (force normally 20 N) this point is displaced despite inflation of the fastening cuff around the femur due to movements of the soft tissues of the thigh Therefore the tube centering is adjusted in order to counteract projection variation on the films The thigh cuffs are inflated before each exposure to about 40 to 47 kPa but are deflated between exposures to allow free circulation in the limbs

For lateral projection of the other knee the gonylaxometer is turned 180 on its central swivel foot so that the tube need not be moved

Measuring on the film The distances between the bony components of the joint are measured on the films The ligaments will normally permit only a limited movement Rupture of a ligament manifests itself on the film as an increased distance between the corresponding parts of the bones Comparison of movement amplitudes may be made with the patient s uninvolved knee or with normal values

Measurement of lateral instability is performed on the a p views using a horizontal viewing box a transparent celluloid film with thin horizontal and vertical lines

scored at right angles to each other is placed on top of the radiographic film Two such celluloid films are used for the measurement

Since the bony contours as well as the lines scored in the celluloid films are of a certain width it is necessary for accuracy and reproducibility to account exactly for how the lines are placed on the film in the measurement

Line l_1 (Fig 2) is placed with its lower edge superimposed on the lower border of the most distal contours of the femoral condyles line l_2 with its upper edge superimposed on the upper edge of the frequently rather broad contours of the most distal radiologic limits of the sockets on the tibia When the edge of the lateral socket is lowest at the extreme lateral point the line is superimposed on this point Lines l_3 and l_4 are placed at right angles to l_2 their outsides being superimposed on the most medial point of the medial contour of the medial tibial condyle and the most lateral point of the lateral contour of the lateral tibial condyle

Placing l_1 in relation to the femoral condyles is never difficult However special conditions apply to the tibial condyles The cartilage-covered part of these condyles is of varying shape The contour medially and laterally may be as regular as illustrated in Fig. 2 but often the cartilage covered joint surface of the condyle may arch out laterally or medially separated from the more distal part of the condyle by a small notch If so lines l_3 and l_4 are superimposed on the most medial and lateral edges of this arch respectively (Fig 3) Bony osteophytes are disregarded in the measurement and the lines placed through them

The following measurements have been made distances a (Fig 2) cut off on l_3 and b on l_4 between l_1 and l_2 in the unloaded knee joint distances c (Fig 4) during forced abduction and d during forced adduction Abduction instability or medial instability may then as suggested by KENNEDY & FOWLER be expressed as c–a and adduction instability or lateral instability as d–b for each limb separately Another possibility is to tabulate the maximum distances c and d between the condyles during load in a material of normal uninjured subjects or the differences between these distances in the right and left knee c_R–c_L and d_R–d_L (for use in unilateral injuries which are by far the most common ones) The distances were measured with a vernier gauge in mm with one decimal

Measurement of anteroposterior instability performed on the lateral film is more complicated It requires an exact identification of the femoral and tibial condyles and of the central contours which on the films represent the structures in the intercondylar tibial area

The lateral femoral condyle may be identified by its large guiding ridge for the patella which starts about 1 cm more proximally on the femur than the patellar surface of the medial femoral condyle (Fig 5) and by the condylopatellar sulcus (limiting groove) which is located to about the middle of the curve of the lateral condyle Moreover the curve of the lateral condyle is usually flatter than that of the medial one

The limiting groove of the medial femoral condyle is located further proximally

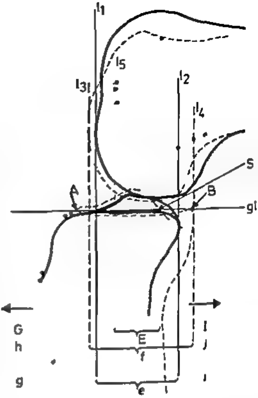

Fig 5 Measuring technique on the lateral view *Solid lines* Lateral femoral condyle lateral tibial condyle and its socket lateral tubercle *Broken lines* Medial femoral condyle medial tibial condyle and its socket medial tubercle *Dotted lines* On the femur Patellar surface of the femur and Blumensaat s line On the tibia Anterior margin tibial tuberosity crest of anterior intercondylar area gl baseline through points A and B S Point of intersection between posterior contour of medial tubercle and baseline gl Lines l_1 to l are perpendicular to line gl Distances E f and e are indicated (no forces applied to the joint) corresponding distances G h and g during application of a p a pulling force (left) and I J and i during application of an a p pushing force (right)

on the condylar curve—at the junction of the proximal third and distal two-thirds or even more anteroproximally

The lateral tibial condyle is identified by tracing the contour of the lateral inter condylar tubercle which proceeds from its summit backwards in an arch evenly convex upwards backwards unlike that of the medial tubercle which drops more abruptly downwards and backwards from its summit The convex arch of the lateral tubercle continues directly in the posterior contour of the lateral tibial condyle (Fig 5) The posterior contour of the lateral tibial condyle is more tapering than the large squared off contour of the medial condyle

The proximal posterior corner of the medial tibial condylar contour does not con tinue in the contour of the medial tubercle but is formed by the junction of the two arcuate contours of the inner and outer limits of the socket This point can always be identified (point B Fig 5) The medial socket is concave and more retroverted than the lateral one its long contour concave upwards may be traced right to the beginning of the medial tubercle This point of intersection is designated A

The measurement is made along a baseline gl through points A and B (Fig 5) All other measuring lines are at right angles to this baseline l_1 is placed as a tangent to the anterior contour of the lateral femoral condyle so that it is superimposed on

Table 1

Standard limits of knee stability in healthy subjects $\bar{X}_n \pm t \times SD$ 17♂+17♀ Abduction/adduction force 9N pushing/pulling force 20 N For 34 subjects $t_{.x}$=2 03

Displacement measured	Parameter	Standard values (mm) $\bar{Y} \pm t_{1x} \times SD$		SD	Upper limit (right–left) $\bar{X} + t_{.x} \times SD$	SD
Medial–valgus–abd	c	Men	5 8–12 1	1 3	1 4	0 4
		Women	5 2– 9 8	1.2		
Lateral–varus–add	d	Both sexes	9 2–16 9	1 9	2.0	0 6
Ant displacement						
Lateral cond	e–g	Both sexes	0 2– 8 8	2.1	3 1	1 0
Medial cond	f–h	Both sexes	0 0– 5 5	1 5	2.5	0 7
Average	((e–g) + (f–h))/2	Both sexes	0 0– 7 0	1 7	2.6	1 5
Central point S	E–G	Both sexes	0 0– 7 1	1 8		
Posterior displacement						
Lateral cond	i–e	Both sexes	0 2– 6 0	1 4	2.9	0 8
Medial cond.	j–f	Both sexes	0 0– 3 4	0 8	1 9	0 5
Average	((i–e) + (j–f))/2	Both sexes	0 8– 4 1	0 8	1 9	0 8
Central point S	I–E	Both sexes	0 1– 5 1	1 2		
Total a–p displacement						
Lateral cond	i–g	Both sexes	3 1–12 0	2.2	3 1	0 9
Medial cond	j–h	Both sexes	0 2– 7 5	1 8	3 1	0 9
Average	((i–g) + (j–h))/2	Both sexes	2 0– 9 5	1 8	2 7	1 8
Central point S	I–G	Both sexes	2.2–10 2	2 0		

the most anterior part of the condylar contour l_2 is placed as a tangent to the anterior contour of the medial femoral condyle and l_5 as a tangent to the anterior contour of the patellar surface of the femur (a short distance from the site where this contour bends downwards and backwards to continue in Blumensaat s line) l_3 is the tangent to the posterior contour of the lateral tibial condyle l_4 to the posterior contour of the medial tibial condyle The proximal cm of the posterior edge of this condyle often forms a rounded ridge—in that event the measurement is made to the posterior contour of this ridge Point S is the point of intersection between the posterior contour of the medial tubercle and the baseline (gl)

Distance e is cut off on gl between l_1 and l_3 distance f between l_3 and l_4 and distance E between l_5 and point S on the lateral view of the unloaded knee joint During traction carrying the tibia forward the corresponding distances are designated g, h and G respectively and during pressure carrying the tibia backwards i j and I respectively Distances e and g represent the position of the lateral tibial condyle in relation to the lateral femoral condyle in the unloaded knee joint and under the influence of traction respectively The difference e–g then expresses the forward displacement of the lateral tibial condyle during traction anterior instability f–h expresses the corresponding forward displacement of the medial tibial condyle

Table 2

Age and sex distribution Abduction/adduction force 9 N in group I 18 N in group II Anteroposterior displacement force 20 N in group I 13 N in group II

Age	Women			Men		
	Total	Group I	Group II	Total	Group I	Group II
20–30	22	15	7	18	13	5
31–52	3	2	1	7	4	3
20–52	25	17	8	25	17	8

E–G represents the anterior displacement measured between more centrally situated points Accordingly this distance is theoretically less influenced by rotation in the joint which may arise during the traction Table 1 gives a survey of the distances measured and the calculated anteroposterior displacements All calculations are performed for the right as well as for the left knee joint and differences between the two sides can thus be assessed

When the proximal extremity of the tibia is carried forward it will be seen that the lateral tibial condyle in the healthy knee joint is displaced considerably more than the medial one This represents internal rotation of the tibia in the 90 flexed knee on a vertical axis (in the longitudinal direction of the tibial shaft) This forced rotation during traction is not equal to the maximally possible internal rotation of the tibia in relation to the femur (pronation) in the unloaded knee joint in 90 flexion The rotation during traction takes place with extended tense ligaments unlike the relaxed ligaments during rest which permit greater rotation Measurement of this rotation was not within the scope of the present investigation and will not be discussed further

The best expression of the total anterior displacement of the tibial condyle is the mean of the anterior displacement of the lateral and medial condyles $((e-g)+(f-h))/2$ E–G is the approximate measure of the total anterior displacement

The same applies to the posterior displacement during pressure displacement of the lateral tibial condyle (i–e) the medial condyle (j–f) and the central part of the tibia (I–E) the total posterior displacement equals $((i-e)+(j-f))/2$ and rotation in this case is supination of the tibia

Material of healthy subjects

Measurements from 50 normal subjects 25 females and 25 males were used for assessing the accuracy of the method from one measurement to the other on the same subject These 50 persons had never had knee injuries diseases or complaints and their knees were clinically and radiologically normal The age and sex distribution appears in Table 2

A test retest procedure in the gonylaxometer was used Each envelope containing one set of radiographic films of the knees of one subject was marked by a 5 digit code number Thereafter the subject s name and code numbers were filed in a sealed envelope The various parameters were measured in randomized sequence not until all subjects had undergone this test retest procedure After the measurements were completed the code was broken so that the duplicate examinations could be com pared No measurements were excluded from the analysis

Results

It was found that parameters a and b varied considerably (i e the neutral position 160° is poorly defined) It was also demonstrated that during slight abduction or adduction the subjects still feel that the knee is relaxed and unloaded and this may explain the varying values found Instead the parameter c was used for medial instability and d for lateral instability The accuracy of the measurement was assessed on the basis of the mutual difference between the duplicate determinations (the difference is designated d) SD = standard deviation of difference = $1/2N\Sigma d$ (THERKELSEN 1968)

In the measurements of lateral and medial laxity parameters c and d the SD = 0 56 mm $SD_d = 0\ 59$ mm were calculated on the basis of measurements on 34 patients 17 males and 17 females (force 9 N) The inaccuracy of each measurement is then $\pm t_i \times SD$ i e less than $\pm 1\ 2$ mm

For anterior displacement (parameter e–g lateral tibial condyle and f–h medial tibial condyle) and posterior displacement (i–e lateral tibial condyle and j–f medial tibial condyle) and total anteroposterior displacement (i–g and j–h respectively) the inaccuracy of the measurement was less than $\pm 2\ 4$ mm at a 95 per cent confidence level

Repeat measurements of the same parameter in the same subject may (without intervening injury or treatment) be expected to fall within these limits

Using the central points for measuring anteroposterior displacement (parameters E–G I–E and I–G) gives the same measuring accuracy except for parameter I–G $\pm 2\ 5$ mm

The use of an abduction force of 18 N in measuring medial instability (investigated in 8 females and 8 males) which the subjects feel as a disagreeably great force doubles the inaccuracy of the measurement to $\pm 2\ 2$ mm

In any one subject the accuracy of the measurement at a reduced traction force of 13 N in the anterior direction (drawer sign) is $\pm 2\ 4$ mm i e of the same magnitude as when using the traction force of 20 N

The standard values defined as $\bar{X} \pm t \times SD$ of the various parameters calculated on the basis of the measurements from the 34 subjects (abduction and adduction force 9 N and traction and pressure force 20 N) appear in Table 1 No difference between the standard values for the right and left leg was found The table shows that

the subject to-subject variation is very marked Therefore the difference between the size of the parameters for the two legs on the same person was analysed and the standard values of this difference calculated As far as abduction and adduction instability is concerned the difference between the two sides was normally less than 2 0 mm With regard to anterior and posterior instability as well as total antero-posterior instability this difference was less than 3 1 mm for both condyles In four of the male subjects traction and pressure forces of 30 N were also applied, yielding values within the same limits There is a statistically significant difference between women and men only in the case of parameter c (p 0 01) The values listed in Table 1 are distances directly measured on the films not corrected for the magnification

The magnification was determined by 21 measurements on the anteroposterior and lateral views of the knee joint by short metal wires placed over various bony prominences close to the skin Range 1 03–1 15 mean 1 08 = 1 1 = 11/10 (or a magnification in the order of 10 per cent on the film)

Discussion

A radiologic report on lateral and medial instability and the drawer sign in the knee joint was first published by KIRCHMAYR (1920) demonstration of lateral and medial instability later by PALMER (1938) and demonstration of the drawer sign by BOHLER (1943) The techniques used have been fairly crude restricted to ascertaining an increased distance between the tibial and femoral condyles in the anteroposterior projection or demonstrating forward or backward displacement of the tibia in the lateral view JONASCH (1958 1968) refined the technique by exposures of abduction and adduction instability in the a p projection but did not describe any exact or well-defined measurement of the distance between the femoral and tibial condyles In an attempt to obtain more constant measurements from one occasion to the next in the same subject and more comparable measurements from one subject to another QUELLET et coll (1969) standardized the force exerted upon the joint in abduction adduction and anteroposterior traction by fastening the thighs and applying traction to the tibia by weights attached to strings over pulleys

The advantage of a hydraulic system acting upon the knee joint is that on repeat examination of the same patient exactly the same force can be reproduced Moreover the set up secures the same projection In these respects the present author agrees with KENNEDY & FOWLER but a disagreement exists on several points concerning the measuring technique which has therefore been described in considerable detail

On the lateral film KENNEDY & FOWLER used a line parallel to the lower edge of the film (bl Fig 6) as a baseline in measuring anteroposterior displacements whereas in the present series the line gl through points A and B (Figs 5 and 6) constitutes the baseline the position of which is thus related to the knee irrespective of its positioning on the film A change in position of the 90 flexed knee in relation to the

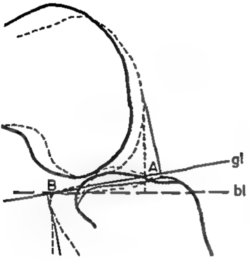

Fig 6 Drawing from a lateral film Distance BA (medial condyles) measured on the baseline gl – 43 mm, while measured on the baseline bl parallel to the lower border of the film it is 36 mm Difference 7 mm Angle between gl and bl 10

lower edge of the film may occur in the author s apparatus depending on the adjust ment to length of lower leg etc This may presumably also occur in the apparatus of Kennedy & Fowler but is not discussed by them A 10 tilting of the baseline from gl to bl (Fig 6) may alter the result of the measurement by 14 to 19 per cent (7 mm in the illustrated case) Thus it is of great importance to fix a baseline on the film related to the tibia

The landmarks used by Kennedy & Fowler for identifying the tibial and femoral condyles are not satisfactory They do not mention the condylopatellar groove of the medial femoral condyle and they describe the posterior contour of the lateral tibial condyle as large and squared off while that of the medial tibial condyle is stated to be more slender and tapering Actually it is just the other way round

Confusion of the posterior contours of the tibial condyles may explain why the anterior displacement found on traction in the normal material of Kennedy & Fowler is different from the present findings They found anterior displacement to be the same for both tibial condyles whereas in the present series there was a considerably greater anterior mobility of the lateral tibial condyle in normal knee joints up to 9 mm as compared with their 5 mm for both tibial condyles (cf Table 1) The value for the medial tibial condyle in the present material was 5 5 mm Kennedy & Fowler also omitted assessing the reliability of the method by repeat measurements More over they analysed only anterior displacement and medial instability

The parameters a and b (corresponding to neutral position 160) were found to be poorly defined Thus the parameter c–a used by Kennedy & Fowler is a poor expression of medial instability Instead the use of $(c_R - c_L)$ is advocated or in cases of bilateral injury the excess measured above the standard values of c to indicate medial instability On the basis of the same considerations parameter [illegible] alone is used for lateral instabilit

Central displacement, e g parameter E–G has proved to be almost equal to ((e–g)+(f–h))/2 which is the mean of the anterior displacement of the two tibial condyles As more ample data are obtained by measuring the displacement of the two condyles separately, the most practical measure of the total displacement is presumably ((e–g)+(f–h))/2 which means that measurement of the central displacement (parameters E–G I–E I–G) is hardly of much importance An abduction/adduction force of 9 N has proved best suited This is not disagreeable to the patients and therefore affords the most accurate measurements as pain conditioned contractions of the muscles are avoided A traction force (in examination for the drawer sign) of 13 N affords reproducible values but is often too slight in the case of muscular individuals Therefore the forces and measuring results listed in Table I should be employed

The measuring accuracy of the apparatus has proved adequate for assessing the results of surgery or other treatment as in a biologic material instabilities in the knee joint of such a small magnitude as 1–2 mm cannot be expected to be improved e g by operation Indeed instability causing discomfort to the patient is empirically of considerably greater extent

For diagnostic use in acute injury to the knee as well as in chronic instability following previous possibly untreated injuries the upper normal limits for the difference between the two knees (rather than the fairly wide range of standard values) have also proved well suited A difference between the two knee joints has to exceed 2 0 mm to fall outside the standard values for lateral and medial instability and 3 1 mm for the drawer sign

Acknowledgements

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SUMMARY

The measurement of anteroposterior instability as well as lateral and medial instability in the knee joint based upon radiologic films exposed while forces are being exerted on the patient in a specially constructed stress apparatus is described Measurements on the films require detailed knowledge of the landmarks of the joint alignment of baselines to special points especially on the lateral projection where anterior and posterior displacement should be measured for each tibial condyle to calculate the mean

ZUSAMMENFASSUNG

Die Bestimmung der anteroposterioren Instabilitat sowie die laterale und mediale Instabilität des Kniegelenkes die sich auf Rontgenfilme stutzt wird beschrieben Diese wurde wahrend der Patient in einem speziell konstruierten Stressapparat langzeitigen Kraften ausgesetzt worden war hergestellt Die Messungen auf den Filmen fordern detaillierte

Kenntnisse der anatomischen Merkmale des Gelenkes Abstechung der Baslinien zu speziellen Punkten besonders auf der Seitenprojektion während die Abweichungen nach vorne und hinten des jeweiligen Tibiakondylus gemessen werden sollte um den Mittelwert zu berechnen

RESUME

L auteur decrit la mesure de l instabilite antéro-posterieure et de l instabilite externe et interne dans l articulation du genou en se basant sur des films radiographiques pris pendant que le genou du malade est soumis à des forces dans un appareil de contrainte mecanique specialement construit Les mesures sur les films necessitent une connaissance detaillee des repères de l articulation l alignement de lignes de base sur des points speciaux en particulier sur les incidences de profil alors que les deplacements anterieurs et postérieurs doivent etre mesurés pour chaque condyle tibial pour calculer la moyenne

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TOMOGRAM RECONSTRUCTION USING AN OPTICOPHOTOGRAPHIC METHOD

PAUL EDHOLM

The new principle of tomography that first gained practical application with the design of the EMI scanner constitutes one of the most important advances in the field of diagnostic radiology The wide interest that this method has aroused since the first machine was constructed in 1972 is perhaps reflected in the variety of labels by which it has been designated Most of the apparatuses employed rely on computer techniques and efforts have been made to design algorithms for the reconstruction of the images that can be handled with the large data volumes required Notwithstanding the remarkably good results achieved with this technique it still has a number of disadvantages including high cost the need for digitalizing data and images and low resolution These shortcomings are avoided by using opticophotographic techniques for the reconstruction of the tomogram in accordance with similar principles but without the aid of computers (PETERS 1973 GORDON & BARRETT 1975 EDHOLM & JACOBSON 1975) One such technique is described in this article

Before describing this system a few related methods will be mentioned In 1940 FRANK patented a technique for producing transverse tomograms where the projecting rays were parallel to the layer TAKAHASHI (1957) described various techniques for producing transverse tomograms based on the same principle of projection The Takahashi principle is of particular interest The rays were generated in a roentgen tube and collimated by passing through a lead slit giving a thin and wide fan beam

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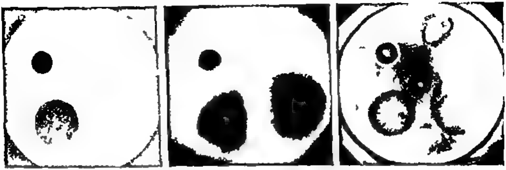


a b c

Fig. 1 a) The object disc b) A Takahashi tomogram of the object disc c)Tomogram produced with a compensated sinogram

After passing through the layer and only that layer the beam hit a film perpendicularly While the patient was rotated about an axis perpendicular to the plane of the beam the film was translated parallel to this axis At each instant a line shaped projection of the layer was recorded on the film During the continuous movement a constantly varying projection of the layer was registered on the film TAKAHASHI developed a series of techniques for constructing an image of the layer from the information contained in the film however these techniques involved a number of defects which made it difficult to produce a transverse tomogram A transverse tomogram formed with the rays parallel to the layer will be referred to as a Takahashi tomogram This is essentially similar to the conventional transverse tomogram and thus shares its imperfections including loss of definition and contrast

With the technique now presented not only a Takahashi tomogram may be produced without technical defects but it is also possible to reconstruct a tomogram similar to images produced by computer tomography (Fig 1 c)

The technique is based on the use of three specially designed apparatuses The first the projection recorder corresponds to the actual scanner in computer tomography it records the projections of the required layer on a film The second the compensator modifies these projections in a way corresponding to the convolution performed by the algorithms used in computer tomography The third the back projector synthesizes a tomogram from the modified projections The three model apparatuses have been designed and built at the Department of Medical Engineering Karolinska Institutet Stockholm

The projection recorder

This apparatus for registering the projections on a roentgen film (Fig 2) bears a close resemblance to the construction of TAKAHASHI The rays from a roentgen tube are collimated with a lead slit giving a fan beam 1 mm thick When the radiation

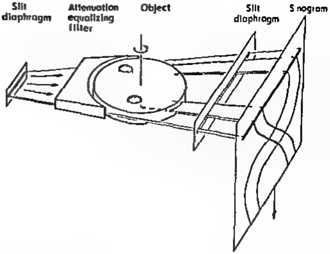


Fig 2 The principle of the projection recorder

has passed through and been attenuated by the object it is collimated by another lead slit before it hits the film at right angles The film is in a cassette furnished with intensifying screens During the exposure the object disc rotates about its own axis which is oriented perpendicular to the beam and at the same time the cassette is moved parallel to this axis

Before the beam encounters the object it is passed through an attenuation equalizing filter This consists of a methacrylate body shaped so as to compensate for the difference in attenuation of rays passing at different distances from the centre of the object The exposure is then fairly uniform over the whole film and the blackening can be kept within the linear portion of the characteristic curve where it is proportional to the logarithm of the exposure

The sinogram

The image on the processed film is composed of all the projections of the object The definition contrast and detail are as in an ordinary film Fig 3 shows a sinogram of a test object consisting of a 10 mm thick methacrylate disc in which are embedded a piece of paraffin wax a piece of wood an aluminium tube and a piece of spongy bone embedded in paraffin wax (Fig 1 a) The bodies in the object disc have been reproduced as interwoven sinusoidal bands a feature that has given rise to the term sinogram for this kind of image Each element in the sinogram represents the projection of a line through the object The reduction in density for this element represents the integrated attenuation along this line

A clearer understanding of the relationship between the object and the sinogram may be obtained by examining a mathematical model of the projection recorder in which the rays are considered to be parallel All points in the object are then represented in the sinogram by sine curves of the same period A given point in the

Fig 3 A sinogram of the object disc

object that initially has the polar coordinates (r_1 ι_1) is represented in the sinogram by a sine curve of amplitude r_1 and phase displacement ι_1 Let a rectangular coordinate system be inserted in the sinogram (Fig 4) where t denotes the distance from the centre line of the sinogram and d the distance along the centre line of the sinogram Let D be the displacement of the sinogram when the object rotates through the angle π The equation for the sine curve will then be

$$t = r_1 \sin(d\pi/D + \iota_1) \tag{1}$$

or

$$t = r_1 \sin(w + \iota_1)$$

where w is the angle through which the object has rotated

All the points in the object are represented in the sinogram by such sine curves Fig 5 illustrates a sinogram with one complete rotation of the object its length thus being 2π Since $\sin \alpha = -\sin(\pi + \alpha)$ the right half of the sinogram will be the negative mirror image of the left half Thus the complete sinogram of length 2π can be divided into four quadrants each of length π Full utilization of the information in the sinogram requires use of only two adjacent quadrants—for example the two quadrants from 0 to π or the two positive quadrants from 0 to 2π In the following the sinogram will generally be represented by the two quadrants from 0 to π

Each point in the sinogram represents the projection of a line in the object In the sinogram reproduced in Fig 4 not only does the sine curve represent the projection of the point (r_1 ι_1) but each point on the curve represents the projection of a line in the set of all possible lines passing through this point (Fig 6 a) The sine curve thus represents a complete projection of the object disc The centre for this projection is the point (r_1 ι_1) and the sine curve is thus a central projection of the disc Conversely any central projection of the object disc is represented as a sine curve described by eq (1) (Fig 6 b) In a projection with parallel rays the centre of the projection must be located at an infinite distance from the centre of the object and r_1 in eq (1) is then infinitely large the curve in the sinogram is then represented as a straight line perpendicular to the midline of the sinogram (Fig 6 c)

Each curve in the sinogram represents a bundle of lines in the object Two examples will be considered

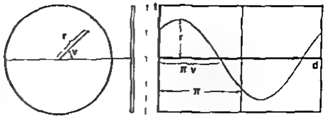


Fig. 4 Parallel projection A point in the object with the polar co ordinates (r_1 v_1) is projected in the sinogram as a sine curve

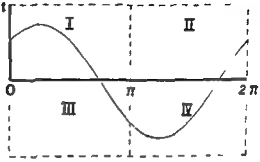


Fig. 5 A complete sinogram divided into four quadrants each of length π Quadrant IV is the negative mirror image of quadrant I and quadrant II of quadrant III

A small circular disc in the object is depicted in the sinogram as a sinusoidal zone (Fig 7) If the polar coordinates of the centre of the disc are (r_1 v_1) and its radius is r_2 the zone in the sinogram will be bounded by the two sine curves

$$t = r_1 \sin(u + v_1) \pm r_2 \tag{2}$$

A sine curve plus or minus a constant term thus represents a set of lines in the object whose envelope constitutes a circular arc with a radius determined by the constant term It should be noted that this set of lines is not a complete projection of the whole object disc It projects only the points of the object outside the small circular disc not the points within it It is then interesting to examine which curves in the sinogram represent a complete projection of the object It can be demonstrated that an arbitrary curve between the upper and lower edges of the sinogram represents a complete projection Curves from the left edge of the sinogram to its right edge and satisfying the condition

$$f(u) = -f(u \pm \pi) \tag{3}$$

also constitute a complete projection This can also be expressed by saying that in order to constitute a complete projection an arbitrary curve that has a given value of t at the left edge of the sinogram must have the same value t but with reversed sign at the right side

A thin lamina in the object with a plane perpendicular to the object disc is con sidered as a second example This is reproduced in the sinogram as a set of sine curves all of which intersect each other in a point representing the projection that is tangential to the lamina (Fig. 8) The two extreme points of the lamina form the two sine curves that bound this set The points in the sinogram that lie within these

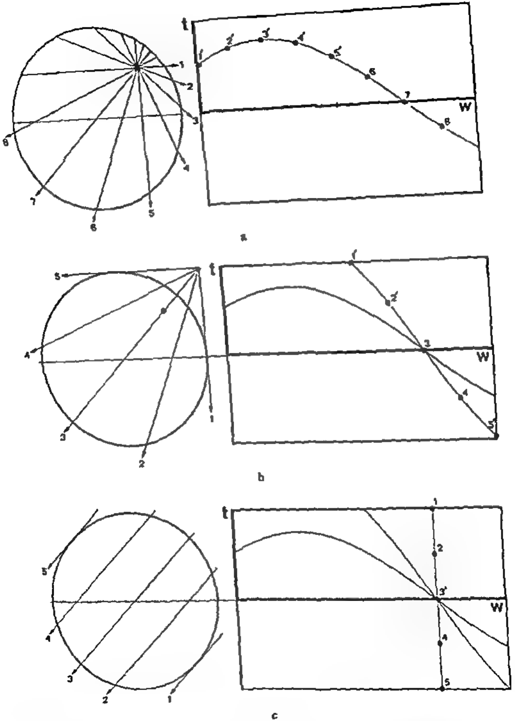


Fig 6 Various sets of lines (1 2 3) traversing the object disc and their projections as points (1' 2' 3') in the sinogram a) Lines passing through a point in the object disc b) Lines originating in a point outside the object disc c) Parallel lines traversing the object disc

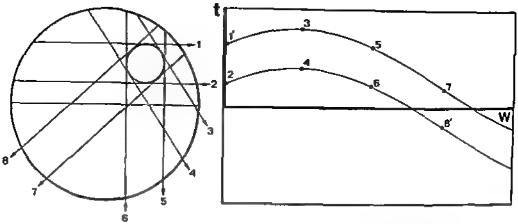


Fig 7 A small circular disc in the object is represented in the sinogram as a zone bounded by two sine curves 1–8 lines tangential to the disc 1–8 their projections as points in the sinogram

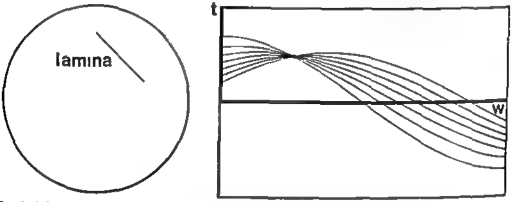


Fig 8 A lamina in the object with its plane oriented perpendicular to the object disc is reproduced in the sinogram as a set of sine curves intersecting in a point which represents the tangential projection of the lamina

two bounding curves all represent lines that intersect the lamina points lying outside the curves represent lines not intersecting the lamina

However in the actual situation where the beam is divergent the relation between object and sinogram is more complicated (Fig 9)

Let f denote the distance between the focus and the sinogram in the projection recorder and g the distance between the focus and the axis of rotation of the object A point in the object having the coordinates $(r_1 \; v_1)$ is then represented in the sinogram by a curve having the equation

$$t = f r_1 \sin(u + v_1) / \{g + r_1 \cos(u + v_1)\} \tag{4}$$

This is a deformed sine curve The expression may be written

$$t = \frac{f r_1}{g}\left[\sin(u + v_1) - \left(\frac{r_1 \sin 2(u + v_1)}{2\{g + r_1 \cos(u + v_1)\}}\right)\right] \tag{5}$$

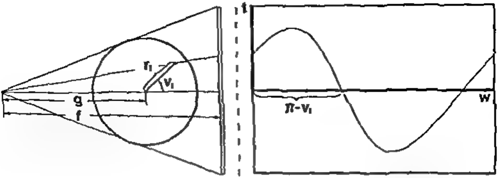


Fig. 9 Divergent beam A point in the object is projected in the sinogram as a deformed sine curve

The first term represents a pure sine curve while the second term represents a sine like curve with twice the period this term may also be said to represent the distortion of the pure sine curve due to the divergence of the beam

Eq (4) represents a central projection of the object with the point (r_1, ε_1) as the centre of projection Just as for the parallel case each curve between the upper and lower borders of the sinogram represents a complete projection of the object It is interesting to analyse whether in the divergent case a curve may be found that represents a projection of the object with parallel rays If the centre of projection (r_1, ε_1) is located at an infinite distance parallel lines in the object disc are obtained Writing eq (4) in the form

$$t = f\sin(w+\varepsilon_1)/\{\cos(w+\varepsilon_1)+g/r_1\} \tag{6}$$

when r_1 approaches infinity

$$t = f\tan(w+\varepsilon_1) \tag{7}$$

This curve thus represents a projection of the object by parallel rays This projection is not simultaneous the different rays in the parallel beam being registered at different times and with different rotations (w) of the object The representation in the sinogram of lines passing through points on a radius and oriented perpendicular to the radius appears in Fig 10

It is evident that if in the divergent case the sinogram is considered to be bounded by the curves

$$t = f\tan w \quad \text{and} \quad t = f\tan(w+\pi) \tag{8}$$

a sinogram is obtained that contains the same information as that in the parallel case where the two quadrants from 0 to π were chosen (Fig 11) Denoting the coordinates in the sinogram in the parallel case by w_p, t_p and those in the divergent case by w_d, t_d

$$w_p = w_d + \arctan(t/f)$$

$$t_p = t_d g/(t_d^2+f^2)^{1/2}$$

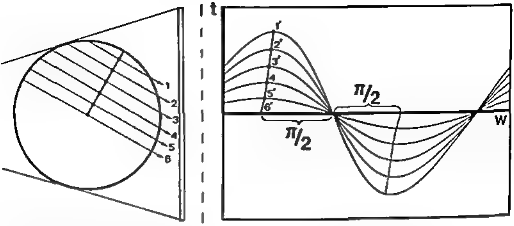


Fig. 10 Points along a radius of the object disc and the corresponding curves in the sinogram 1-6 a set of parallel lines through these points perpendicular to the radius 1'-6' the points representing these lines in the sinogram

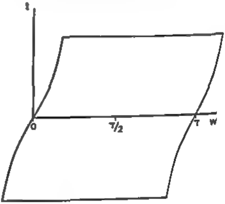


Fig. 11 Sinogram obtained with divergent rays The lines bound an area corresponding to a rectangular sinogram obtained with parallel rays

The back projector

The theory underlying the function of this apparatus is shown diagrammatically in Fig 12 The back projector generates a tomogram of the object from the image in the sinogram A given line in the object is projected as a point in the sinogram and this point is projected back as a corresponding line on a photographic film The line has the same relative position in the film as the corresponding line in the object

The sinogram is passed under a slit diaphragm where it is illuminated by a linear light source The orientation of the slit is such that the slit selects from the sinogram those points representing a complete parallel projection of the object Thus the slit should have the same shape and orientation as the curve (8) This curve is a tangent function As the angle subtended by the part of the curve passing through the sinogram is very small the curve can be approximated to a straight line oriented

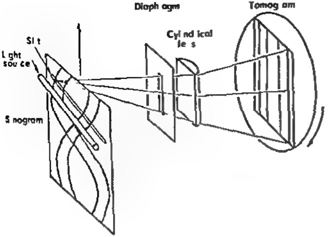


Fig 12. Principle of the back projector

at a certain angle to the centre line of the sinogram The points in the sinogram that are projected through the slit thus represent a set of parallel lines in the object Each such point is projected on the film as a straight line through a cylindrical lens and all the points under the slit form on the film a rectangular field of parallel lines corresponding to the set of parallel lines in the object The sinogram moves under the slit at constant speed and the film rotates synchronously The rotation of the film corresponds to that of the object when the sinogram was exposed All the projections are thus transferred to the film

The divergence of the rays in the projection recorder gives rise to an image error A line in the object at distance a_0 from its centre is projected in the sinogram as a point at distance a from the centre line (Fig 13 top) If the projecting ray makes an angle α with the central line

$$a_0 = g \sin \alpha \quad \text{and} \quad a = f \tan \alpha \tag{10}$$

No constant relationship exists between a_0 and a when a_0 varies In the back projector on the other hand there is a constant relationship between the distance a_s in the sinogram and the distance a_t of the corresponding line from the axis of rotation in the tomogram Thus the relationship between a_s and a_t is not constant The change in the ratio a_t/a_s as a_0 varies is shown by a curve 0 in Fig 14 The error so incurred is eliminated by placing a diaphragm in the back projector between the cylindrical lens and the sinogram The rays from the points in the sinogram representing large values of a_0 then pass through the peripheral part of the cylindrical lens Because of the spherical aberration they are focused slightly nearer the centre of the tomogram than if there was no diaphragm (Fig 13 bottom) The path of the rays from the sinogram through the diaphragm and the cylindrical lens has been simulated in the computer By a series of such calculations a position of the diaphragm could

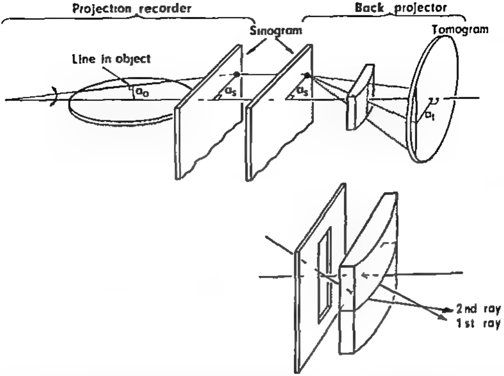


Fig 13 Top Ray path in projection and back projection No diaphragm is used A line in the object at distance a_0 from the centre is projected in the sinogram as a point at distance a_s from the centre line In the back projector this point is projected as a line at distance a_t from the centre of the tomo gram The ratio a_t/a_0 is not constant when a_0 varies and this incurs a projection error Bottom This error is corrected for by using a suitably placed diaphragm The 1st ray is produced without the diaphragm The 2nd ray produced with the diaphragm passes through a peripheral part of the lens where the error is compensated for by the spherical aberration

be chosen resulting in a practically constant relationship between a_0 and a_t (Fig 14 curve 6)

With the projection recorder and the back projector a true Takahashi tomogram with correct geometry may be produced It has the same properties as an ordinary transverse tomogram namely low definition and contrast and interfering spurious contours (Fig 1 b) In the Takahashi tomogram each image element has received an exposure corresponding to the summation of all the rays through the object and through a centre that corresponds to the image element in question Each image element is thus affected by the whole object it may thus be considered to behave as a detector with a detector field extending from its corresponding point in the object over the whole object and diminishing in sensitivity Otherwise formulated each detail in the object produces a signal field that emanates from its corresponding point in the image over the whole image with a strength inversely proportional to the distance from this point This is the cause of the low quality of conventional transverse tomograms

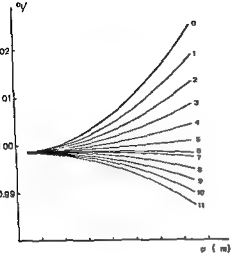


Fig 14 Computer-calculated curves The ratio a_t/a varies with a_0 Curve 0 no diaphragm Curves 1–11 show the effect of a diaphragm located at different distances from the cylindrical lens Curve 6 the effect of the diaphragm in its chosen position giving a practically constant relationship between a_0 and a_t

Compensation

In computer tomography a given image element is affected only by the correspond ing object element Thus each detail in the object produces a signal that only reaches the corresponding image element and does not affect other parts of the image This is the reason for the remarkably high quality of computer tomograms

A similar effect is obtained with the present technique by reducing the size of the signal field generated by an object element so that its effect is confined largely to the corresponding image element This is achieved through a process whereby the effect of most of the field outside the image element is eliminated The essentials of this process are as follows

Consider a homogeneous object disc that together with the attenuation equalizing body produces a uniform and constant background density over the whole sinogram In the object disc is inserted a small cylindrical element with a radius corresponding to the resolution of the tomogram and with a higher attenuation than the rest of the object This element gives rise to an element track in the sinogram the reduction in density of which is proportional to the increase in attenuation of the element (Fig 15) The back projector projects such an element track as a light element band on the tomogram film this band produces a slightly greater exposure than does the light from the rest of the sinogram The element band rotates in relation to the film about a centre in the image element that corresponds to the object element This image element will be covered by the element band during the whole exposure and will receive an increase in density that is proportional to the increase in attenua tion of the object element If the exposure for the rest of the film were to correspond to the background density of the sinogram the reproduction would be correct However the light element band also sweeps the rest of the film and thus increases

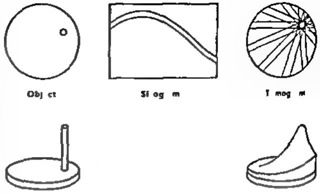


Fig. 15 Upper left The object with an attenuating element Middle The sinogram with the resulting element track Upper right The tomogram receives the back projection of the element track as a light element band which rotates about the image element Lower left Relief depicting a perfect image of the object disc Lower right Relief representing the signal field from the object element (the conventional summation tomogram)

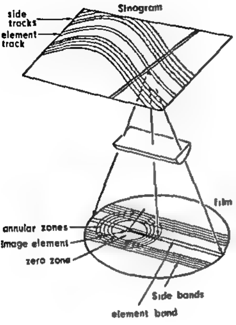
its exposure It is this increase that accounts for the extended signal field of the object element (Fig 15 lower right)

In computer tomography the signal field from a given element of the object is in theory completely eliminated outside the image element This is achieved because the elements in the object and the image are relatively large In the present photographic technique the image and the object elements are relatively small corresponding in size to the resolution of the system As a result the attenuation of an object element is much too small to be represented in an image element For this reason no attempt is made to eliminate the signal field entirely outside each element of the object but instead to limit the signal field to a zone of a certain width around the image element This zone will in the following be referred to as the zero zone The method by which the signal field is eliminated is in principle similar to that for the reconstruction algorithms intended for computer tomography as presented by CHO (1974) and EDHOLM (1975) It is essentially a convolution of the projections registered in the sinogram before they are projected back to form the tomogram This modified method of compensation may be explained as follows

Let the zero zone be surrounded by annular zones (Fig 16 a) The element track in the sinogram may be considered to be bordered by side tracks, which are projected on the tomogram as side bands adapted to the annular zones The first annular zone is the one just outside the zero zone the second the one outside the first and so on. Side bands and side tracks are numbered according to the zones to which they correspond

An increase in the density of the first side track in the sinogram will result in a reduction of the light from the first side band The exposure for the first annular zone will therefore be reduced by the darker first side band by an amount that may compensate for the increase in exposure from the light element band

The first side band covers a much greater area of the first annular zone than does the element band (Fig 16 b) The required increase in density of the first side track will therefore be less than the reduction in density of the element track The relationship between these quantities is constant and may be calculated from those areas



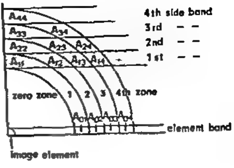


Fig 16 a) Back projection of the sinogram on the film that is to be the tomogram. The image element on the film is surrounded by a zero zone and a system of annular zones To this corresponds a system of side tracks in the sinogram b) A quadrant of the system of zones element band and side bands in the film The side bands cut off the areas A_{11} A_{33} etc. from the annular zones

of the first annular zone that are covered by the element track and the first side track In the second annular zone the increase in exposure due to the element track will be partly offset by the increase in density of the first side track Complete compensation is obtained when the density of the second side track is also increased The other annular zones are similarly compensated in turn The coefficients for the increase in density for the various side tracks are calculated from the component areas of the annular zones occupied by the element band and side bands (a quadrant showing these areas appears in Fig 16 b) With the notation in the figure the various coefficients k_1 k_2 ... k_n are calculated from the following system of equations

$$A_{01}+k_1A_{11}=0$$
$$A_{02}+k_1A_{12}+k_2A_{22}=0$$
$$A_{03}+k_1A_{13}+k_2A_{23}+k_3A_{33}=0$$

$$A_{0n}+k_1A_{1n}+\dots k_nA_{nn}=0$$

If the diameter of the object element is taken as 0.3 mm the diameter of the zero zone is 3 mm and the width of each annular zone as 0.3 mm the first 10 coefficients will be

$k_1=-0.2330$ $k_2=-0.0169$ $k_3=-0.0502$ $k_4=-0.0225$ $k_5=-0.0216$
$k_6=-0.0155$ $k_7=-0.0130$ $k_8=-0.0106$ $k_9=-0.0090$ $k_{10}=-0.0077$

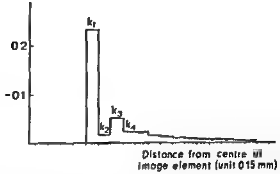


Fig 17 Values of the compensation coefficients The unit on the horizontal axis is the radius of the image element

The coefficients fall rapidly to very low values (Fig 17)

The density of each side track in the sinogram must thus be increased by an amount that is equal to the reduction in density of the element track multiplied by the respective coefficient The increases in density of the side tracks can be produced on a special negative by contact copying the element track the exposures then being chosen so as to correspond to the coefficients

The compensator

In this apparatus a negative is produced that contains side tracks with the appropriate densities to compensate for the element track this is done by a special process that contact copies element tracks on a new film the compensating mask The finished mask is then combined with the sinogram and the combination is used in the back projector

Since all the side tracks are identical in shape to the element track being only translated the element track may be successively copied on the various side tracks of the mask Between each copying operation the mask is translated in relation to the sinogram through a distance corresponding to the width of a track (Fig 18) The exposure light which is controlled by a function generator is then varied so that it always corresponds to the coefficient for the side track of the mask located beneath the element track The mask is developed and combined with the sinogram the combination constituting a compensated sinogram When this is used in the back projector a correct representation of the object element in the image element is obtained Outside the zero zone the signal field is eliminated The density of the rest of the tomogram is thus unaffected by the object element

If the object disc contains two object elements they will form two element tracks in the sinogram When this sinogram is used in the compensator the mask will contain two systems of side tracks one for each element track (Fig 19) In the back projection of the compensated sinogram both object elements are reproduced on their appropriate image elements Outside the zero zones the two signal fields are eliminated by the two side track systems The object may be filled with object elements the compensating mask contains side track systems for all the elements

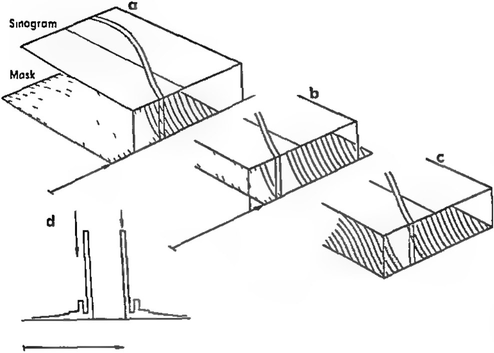


Fig 18 Formation of the compensating mask by staged translation and contact copying of the element track in the sinogram on negative film (the mask) For clarity the two films have been separated in the diagram. a, b) Two stages in the contact copying process c) The finished compensating mask is combined with the sinogram to give a compensated sinogram d) The function controlling the exposure light intensity in the staged contact copying of the element track Arrows indicate the exposures corresponding to stages a and b

As is seen from the compensated tomogram of the object disc in Fig 1 c the similarity to the direct image (Fig 1 a) is greater than for the uncompensated tomogram (the Takahashi tomogram in Fig 1 b)

The effect of the compensation may also be described in the following way Without compensation each image element has a detector field covering the whole object disc and is affected by all the details in this field With the described compensation the detector field is reduced to a circular zone which is uncompensated The increase in density in each image element is proportional to the mean attenuation of the rays that pass through the corresponding object element and that have been attenuated over a distance in the object disc corresponding to the diameter of the zero zone

The compensation may be performed with different radii of the zero zone When this radius is large enough to cover the whole object disc a conventional transverse tomogram is obtained Even with a relatively large zero zone there is a marked improvement of the tomogram The resolution of the tomogram varies to only a moderate extent with the size of this zone The contrast on the other hand is directly

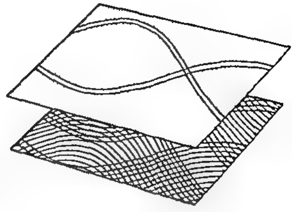


Fig 19 Sinogram with two element tracks and beneath it the corresponding compensating mask Irrespective of the position and number of element tracks in the sinogram as a result of the compensation all acquire compensating side track systems

proportional to the diameter of the zero zone This is the reason why with this method it is an advantage to have a larger diameter for the zero zone than for the image element the contrast would otherwise be too small

Deviations from the correct solution

The procedure presented for producing a compensated tomogram has certain theoretical imperfections In contact copying with a negative material having a gamma value of unity it is possible to obtain an image that within the linear part of the film s characteristic curve has variations in density that correspond almost exactly to those of the original It is thus possible to reproduce the density variations of an original on a negative to a high level of accuracy The signals in the sinogram represent reductions in density and to obtain a theoretically correct image the density values would have to be converted in both compensation and back projection In the present procedures it is not the density values that are summed but the light transmitted by the various parts of the sinogram and this incurs a theoretical error If the variations in density in the sinogram are moderate the error will be negligible and the compensated tomogram may be considered to give a true image of the attenuation values of the object

Discussion

It is very difficult to predict the practical value of the method The model apparatuses in which the method has been tried out have some technical imperfections Almost all the deficiencies in the finished image may be traced to such causes For instance the circular disturbances in the tomogram are caused by imperfections in the cylindrical lens in the back projector These imperfections would presumably be greatly reduced in a full scale prototype However despite the shortcomings of the model apparatuses the method is feasible and enables images of a layer with the desired characteristics to be obtained—that is an image corresponding to a direct radiographic view of the layer

The basic steps in the proposed method are the same as in computer tomography Projections of the layer are recorded convoluted or filtered and back projected The differences are that in computer tomography all these steps are performed dis cretely with a finite number of projecting rays projections and image points whereas the proposed technique is an analogue one with no discrete steps The method seems *to offer a higher photographic resolution than computer tomography* on the other hand the contrast sensitivity is lower

SUMMARY

Description is given of the reconstruction of a tomogram similar to a computer tomogram without recourse to a computer This is achieved by the use of three special apparatuses in which photographic and optical methods are employed

ZUSAMMENFASSUNG

Beschreibung der Rekonstruktion eines Tomogramms ahnlich dem Komputer Tomogramm ohne Verwendung eines Komputers Dieses wird durch Verwendung von drei Spezial apparaturen bei denen photographische und optische Methoden verwendet werden erreicht

RESUMÉ

Description de la reconstruction d une tomographie semblable à une tomographie avec ordinateur sans avoir recours a un ordinateur Ceci est realisé au moyen de trois appareils spéciaux dans lesquels on utilise des méthodes photographiques et optiques

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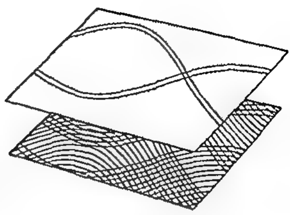

Fig 19 Sinogram with two element tracks and beneath it the corresponding compensating mask Irrespective of the position and number of element tracks in the sinogram as a result of the compensation all acquire compensating side track systems

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THROMBOSIS OF THE INTRAORBITAL VEINS AND CAVERNOUS SINUS

GUDRUN BRISMAR and JAN BRISMAR

If the superior ophthalmic vein is not or only incompletely filled at orbital phlebography this is a definite indication of pathology (LLOYD 1972 BRISMAR 1974) provided an adequate examination technique is used This finding indicates either an occlusion of the vein or increased pressure When the cause is increased venous pressure a repeat forceful injection of the contrast medium may fill the vein possibly disclosing venous displacement in tumor cases or rapid washout of the medium in cases with a carotid-cavernous fistula (BRISMAR & BRISMAR 1976) Occlusion of the vein may be caused by compression from a mass lesion by obstruction from an inflammatory process or by a primary venous thrombosis The differentiation between a tumor and a non tumorous condition is sometimes extremely difficult (BRISMAR et coll 1975 1976) When the occlusion is caused by a tumor concomitant displacement of the vein would be expected However as space is restricted tumors in the orbital apex at the superior orbital fissure or at the skull base often appear as simple venous occlusion at phlebography (HANAFEE et coll 1968 HANAFEE 1972 LLOYD) In some instances the clinical course makes the presence of a local malignant lesion improbable despite the fact that extensive examinations have not disclosed the underlying disorder

The purpose of this report is to present the radiologic characteristics in 8 such cases and to discuss the differential diagnoses

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Submitted for publication 12 April 1976

Table

Radiologic and biopsy findings In all cases conventional skull films were normal special ENT examination was not performed in case 1 but normal in all remaining cases

Case No	Sex and age	Skull base tomography	Carotid angiography side of lesion	Encephalo graphy	Brain scan	Nasopharynx biopsy
1	F 63	0	—	—	—	—
2	F 56	0	—	—	—	—
3	F 63	0	0	0	—	0
4	M 58	0	occlusion of VOS posterior segment	0	0	—
5	M 72	—	0	0	—	—
6	F 53	0	0 (bilat)	0	—	0 (multiple)
7	M 72	—	0	—	0	—
8	F 44	—	narrowing of carotid siphon*	slight brain atrophy*	normal*	0

* Later increasingly abnormal findings 0 = no abnormality — = not performed

One of the present cases (case 8) has previously been described (BRISMAR et coll 1976) and is therefore only briefly discussed The case histories and the ophthalmologic findings of the remaining seven patients are summarized in the legends of Figs 1 to 7 illustrating the phlebographic appearances The results of other examinations are presented in the Table The detailed ophthalmologic findings will be further discussed in a separate report (BRISMAR & BRISMAR 1977)

The ocular motor nerves (N III IV and VI) together with the ophthalmic nerve (the first division of N V) enter the orbit through the superior orbital fissure and are thus prone to be affected by lesions restricting the width of the fissure The resulting complex of symptoms and signs is known under different names—superior orbital fissure syndrome migraine ophtalmique painful ophthalmoplegia Rochon-Duvigneaud syndrome—and is characterized by restriction of ocular movements ptosis and affection of the first division of the trigeminal nerve The optic nerve enters the orbit through the optic foramen and should thus not be affected in a pure superior orbital fissure syndrome—visual impairment suggests involvement of the orbital apex where the optic nerve is located close to the nerves that enter through the superior orbital fissure In clinical practice the differentiation is more difficult as a retroorbital lesion may involve both the optic foramen and the superior orbital fissure The superior orbital fissure syndrome has been described following trauma neoplasms and syphilitic tuberculous or non specific inflammatory lesions (ROGER & ALLIEZ 1935 LAKKE 1962) It has also been described as a recurrent disorder of unknown etiology exhibiting a dramatic response to steroid treatment the Tolosa-Hunt syndrome (HUNT et coll 1961 SMITH & TAXDAL 1966 MATHEW & CHANDY

Fig 1 Case 1 Glaucoma simplex Increasing slight proptosis of the left eye during 4 years Orbital phlebography Semiaxial view Occlusion of the posterior part of the widened and tortuous left superior ophthalmic vein (↦) Filling of the left cavernous sinus (↠) through collaterals Right superior ophthalmic vein appears normal During a further observation time of 3½ years no change of orbital state

a b

Fig 2 Case 2 Diplopia for 8 months On acute deterioration with right ptosis and slight proptosis of the right eye 4 months before admission palsies of the right N III N IV and N VI were confirmed Almost complete clinical regression on admission Orbital phlebography a) Semiaxial b) oblique lateral view Occlusion of the posterior part of the irregularly widened right superior ophthalmic vein (↦) Right cavernous sinus (↠) filled through collaterals Normal left superior ophthalmic vein (→) Repeat orbital phlebography after 3 months yielded identical results No recurrence during a further observation period of 4 years

1969 SONDHEIMER & KNAPP 1973) In a few cases with the Tolosa–Hunt syndrome examination of specimens obtained either at autopsy (TOLOSA 1954) or at surgery (LEVI et coll 1975) has disclosed non specific granulation tissue in the region of the cavernous sinus As the ocular motor nerves and the trigeminal nerves are located close together also in the region of the cavernous sinus (N VI runs together with the carotid artery through the sinus while N III N IV and N V are located in the lateral wall of the sinus) pathology in the cavernous sinus may produce a syndrome identical to the superior orbital fissure syndrome In some cases the involvement of also the second division of the trigeminal nerve (leaving the middle cranial

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4	M 58	0	occlusion of VOS posterior segment	0	0	—
5	M 72	—	0	0	—	—
6	F 53	0	0 (bilat)	0	—	0 (multiple)
7	M 72	—	0	—	0	—
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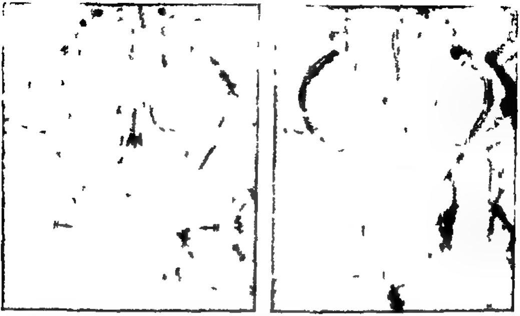
a b

Fig. 5 Case 5 Sudden onset of left eye pain followed by severe headache nausea light intolerance vomiting dizziness diplopia and slightly impaired hearing acuity On admission 3 days after onset partial N III and N IV palsies with slight ptosis on the left side as well as left complete N VI paresis slight proptosis and slight venous dilatation of the conjunctiva Orbital phl bography a) Semiaxial b) oblique lateral view Incomplete filling of the posterior part of left superior ophthalmic vein (↦) and left cavernous sinus (↠) Normal appearance of the same structures on the right side Within 1½ month complete clinical regression no recurrence during a 20-month observation period

The cavernous sinus and the nerves passing through it or in its wall may be involved in a variety of disorders skull base tumors pituitary tumors inflammatory lesions arterial aneurysms carotid cavernous fistulas as well as primary venous thrombosis The latter condition was before the era of antibiotics a feared complication in bacterial infect ons of the face caused by a spread of the infectious process through veins draining into the cavernous sinus Non eptic thrombosis of the posterior part of the ophthalmic vein and of the cavernous sinus has been described secondary to malignant tumors i the skull base or nasopl arynx (GODTFREDSEN 1964) or to trauma (EAGLETON 19(_) and also as a pri iar r ler (VON RAD 1971 VON RAD et coll 1971 TORNOW 1971) with a sympt mimicking that of the superior orbital fissure syndrome VON RAD sugg at several of the cases previously reported in the literature as superior orb i f e syndrome or Tolosa-Hunt syndrome might in fact have had aseptic ca rn us inus thrombosis

As a thrombus originating in the cave r us sinus may propagate into the orbital veins a phlebographic differentiation betw en an occlusion originating in the superior orbital fissure and a cavernous sinus hrombosis is only possible in cases with a filling defect of limited size This appeared in two of the present cases In one of them (case 5) the cavernous sinus was incompletely filled on one side (Fig 5) in the other (case 6) the cavernous sinus was deficiently filled bilaterally (Fig 6 a)



a b

Fig. 6 Case [redacted] Acute onset of nausea headache and right N VI paresis 2 months before admission 19 days after onset of right side symptoms also a left [redacted] VI paresis developed Orbital phlebography a) On admission incomplete filling of right and left cavernous sinus (↔) b) 3 months later filling of cavernous sinuses was improved although still incomplete The N VI palsies slowly improved but at the time of the repeat phlebography as well as a further 3 months later episodes of right optic neuritis occurred rapidly reversed by steroid treatment The further course is not known

In the latter case a repeat phlebography after the regression of symptoms and signs demonstrated improved filling of the cavernous sinus bilaterally (Fig 6 b) These two cases clearly belong to the category of cavernous sinus thrombosis

In 3 of the cases (Nos 3 4 7) the radiologic differentiation between a primary cavernous sinus thrombosis and an occlusion of the vein at the superior orbital fissure was impossible A supplementary skull base phlebography through the inferior petrosal sinus might have given additional information concerning the extension of the venous occlusion into the cavernous sinus but was not performed in either of the cases

The phlebographic findings in two cases (Nos 1 2) were those of an irregular widening of the affected superior ophthalmic vein anterior to a complete occlusion in the posterior part of the orbit (Figs 1 2) In both cases multiple small irregular collaterals bypassed the occlusion permitting a filling of the cavernous sinus In one of these patients (No 2) a phlebography performed 2 months previously at another hospital had not permitted any filling of the veins in the affected orbit At the time of the second phlebography (Fig 2) clinical improvement had already commenced Though differences in technique may account for the different phlebographic appearances at the two examinations it is equally probable that the phlebo-

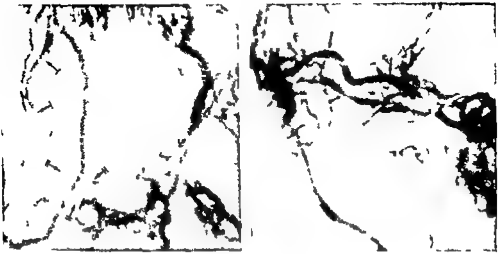


Fig 7 Case 7 Four month history of pain in the right eye followed by right N III and N VI palsies impaired visual acuity on the right side and nausea Orbital phlebography a) Axial b) oblique lateral view Lumen of the right superior ophthalmic vein (⟼) irregular with occlusion in the posterior part of the orbit Incomplete filling of anterior part of right cavernous sinus (⟼) Normal left superior ophthalmic vein (⟶) Complete clinical regression within 4 months followed by a 2 month period of similar symptoms and signs on the left side with subsequent complete clinical regression No recurrence within another 6 months the further course is not known

graphic improvement was real and that the development of collaterals in fact accounted for the clinical improvement A further phlebography another 3 months later when the clinical symptoms had completely disappeared demonstrated the same finding as did the second phlebography In case 1 the clinical symptomatology was that of an intraorbital tumor with no evidence of affection of the ocular motor nerves or the trigeminal nerve In spite of this it is possible that cases 1 and 2 represent an end stage of the same disease whether this be a primary thrombosis or a superior orbital fissure syndrome of some other etiology

In case 8 the clinical as well as the radiologic findings (occlusion of the left superior ophthalmic vein slight stenosis of the intracavernous part of the left internal carotid artery) were originally considered as indicating a Tolosa–Hunt syndrome The future course in this case with involvement of multiple cerebral arteries proved that the patient had a generalized cerebral vascular disorder

Orbital and skull base phlebography are the only methods to demonstrate or exclude thrombosis of the cavernous sinus or orbital veins with any degree of certainty (TORNOW) even if angiography in single cases (case 4) may demonstrate the venous occlusion The clinical possibility of venous thrombosis or occlusion in these regions thus constitutes an important indication for orbital phlebography even in those centers where the availability of recent sophisticated techniques such as computed tomography and orbital ultrasound has reduced the need for phlebography in

the evaluation of intraorbital tumors It should in this context be emphasized that intraorbital or cavernous sinus thrombosis sometimes clinically mimics an intraorbital tumor

As previously pointed out (BRISMAR et coll 1976) it must be remembered that venous occlusion is a non specific sign that may also be caused by disorders such as tumors of the skull base or nasopharynx As these conditions clinically may imitate cavernous sinus thrombosis all patients with a tentative diagnosis of thrombosis of the cavernous sinus or posterior part of the ophthalmic vein should be subjected to tomography of the skull base as well as to nasopharyngoscopy with biopsy before the diagnosis of primary thrombosis is definitely established

SUMMARY

Eight cases with phlebographic appearances consistent with aseptic thrombosis of the cavernous sinus or of the posterior part of the superior ophthalmic vein are presented The clinical course is briefly described and the phlebographic findings and possible differential diagnoses discussed Even if recent methods may obviate the need for phlebography in the demonstration of orbital tumors in certain cases the possibility of intraorbital or cavernous sinus thrombosis constitutes an important indication for phlebography

ZUSAMMENFASSUNG

Acht Falle mit einem phlebographischen Befund der mit einer aseptischen Thrombose des Sinus cavernosus oder des hinteren Teils der oberen Augenvene ubereinstimmt werden beschrieben Der klinische Verlauf wird kurz berichtet und die phlebographischen Befunde und moglichen Differentialdiagnosen diskutiert Es wird hervorgehoben dass wenn auch neue Methoden den Gebrauch der Phlebographie zum Nachweis von orbitalen Tumoren in gewissen Fällen erubrigen die Moglichkeit einer intraorbitalen Thrombose oder einer Thrombose des Sinus cavernosus eine bedeutungsvolle Indikation zur Phlebographie dar stellt

RÉSUMÉ

Les auteurs presentent 8 cas ayant des aspects phlébographiques compatibles avec le diagnostic de thrombose aseptique du sinus caverneux ou de la partie postérieure de la veine ophtalmique supérieure ils décrivent brièvement l évolution clinique et les signes phlébographiques ainsi que les diagnostics differentiels possibles Ils insistent sur le fait que meme si des méthodes recentes peuvent remplacer la phlébographie dans la mise en évidence de tumeurs orbitaires dans certains cas la possibilité d une thrombose intra orbitaire ou du sinus caverneux constitute une indication importante de la phlébographie

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ANOMALY OF ANTERIOR CEREBRAL ARTERY

A case report and embryologic considerations

J BRISMAR R ACKERMAN and G ROBERSON

At a routine post mortem examination TURNBULL (1962) on one side found unilateral agenesis of the internal carotid artery while on the other side a still more rare anomaly was found the internal carotid artery divided beneath the optic chiasm into two wide branches the medial ascending between the optic nerves and branching to supply both pericallosal arteries The anterior cerebral arteries were threadlike

ISHERWOOD & DUTTON (1969) angiographically demonstrated the same anomaly in two patients examined because of subarachnoid hemorrhage In one patient unilaterally in the other bilaterally the anterior cerebral artery was replaced by an anomalous vessel originating from the internal carotid artery at the level of the ophthalmic artery In one of the cases an aneurysm was demonstrated at the site where a normal anterior cerebral artery would have taken origin in that case the course of the anomalous vessel beneath and medial to the optic nerve was confirmed at surgery An error in the complex development of the ophthalmic artery and persistance of primitive arterial anastomosis in the chiasmal region were suggested as two possible explanations for the anomaly

In this report a similar case is presented and possible embryologic explanations for this anomaly as well as for other arterial anomalies of the same region are discussed

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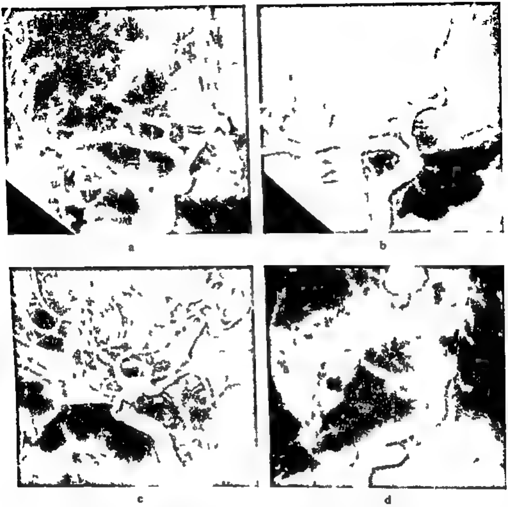

Fig 1 Internal carotid angiography a) A p ; b) oblique transorbital a p c) lateral and d) axial views Abnormal vessel (←→) from carotid siphon supplying right pericallosal artery Anomalous posterior temporal artery (←—) originating from middle cerebral artery Posterior communicating artery (←•)

Case report

The patient was a 39 year old lefthanded man who in his youth had been subject to several corrective facial operations because of multiple congenital defects right anophthalmia agenesis of right mandible harelip with cleft palate and deformity of the nose

Half a year before admission the patient suffered from headache for more than a month Two months later he noted stumbling and dragging of the left leg and weakness of the left arm and hand as well as numbness of the left side of the body Another two months later leftsided hemiparesis leftsided sensory loss and leftsided hyperreflexia were confirmed at a neurologic examination EEG and isotope brain scan were normal Symptoms and signs thereafter successively decreased and on admission had almost completely disappeared The

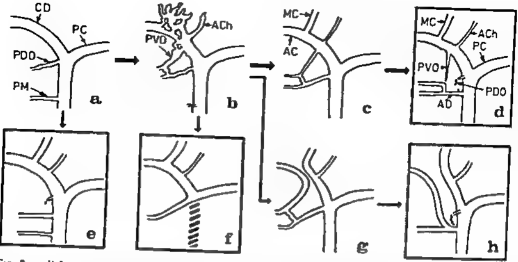

Fig 2 a–d) Normal development of adult ophthalmic artery according to PADGET (schematic) from 5 to 20 mm crown rump length e h) Possible explanations for different observed anomalies e) double ophthalmic arteries f) posterior cerebral origin of ophthalmic artery g) h) present anomaly i e anomalous vessel connecting carotid siphon and pericallosal artery AC = anterior cerebral artery ACh = anterior choroidal artery AO = adult ophthalmic artery CD = cranial division of internal carotid artery MC – middle cerebral artery PC = posterior communicating artery PDO = primitive dorsal ophthalmic artery PM – primitive maxillary artery PVO = primitive ventral ophthalmic artery

findings were considered as compatible with a slowly resolving vascular episode and the patient was referred to computer tomography and cerebral angiography to rule out tumor aneurysm or arteriovenous malformation

Computer tomography demonstrated a well defined rightsided suprasellar lesion with low attenuation most probably a lipoma extending down to the right cerebellopontine angle and measuring almost 20 mm 30 mm This lesion slightly shifted the fourth ventricle to the left The third ventricle and the lateral ventricles were moderately dilated

Rightsided internal carotid (Fig 1) and leftsided vertebral angiography confirmed the presence of an avascular rightsided middle fossa mass extending down into the posterior fossa

In addition the anterior cerebral artery was found to be replaced by an anomalous vessel originating from the internal carotid artery at the level of the ophthalmic artery and passing upwards medially to supply the pericallosal artery

A second vascular anomaly was also found A posterior temporal branch originated from the proximal part of the middle cerebral artery passed backwards-downwards on the medial side of the temporal lobe and then laterally below the temporal lobe to supply its posterolateral aspect (this anomaly will not be further discussed)

The right posterior communicating artery was filled and had a normal origin

Embryology

In her now classic work on the development of the cranial arteries in the human embryo PADGET (1948) devoted one section to the complex development of the

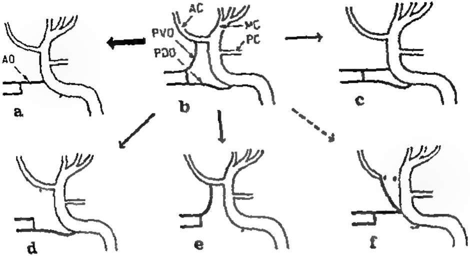

Fig 3 a b) Normal development of adult ophthalmic artery according to LASJAUNIAS and MORET (schematic) from 5 to 20 mm crown rump length c–e) Possible explanations for different observed anomalies c) double ophthalmic arteries d) cavernous origin of adult ophthalmic artery e) anterior cerebral origin of adult ophthalmic artery f) Possible explanation for the present anomaly i.e. anomalous vessel connecting carotid siphon and pericallosal artery AC = anterior cerebral artery AO = adult ophthalmic artery MC = middle cerebral artery PC = posterior communicating artery PDO and PVO = primitive dorsal and ventral ophthalmic arteries

ophthalmic artery The results obtained through graphic reconstruction of 22 sectioned embryos with 3 to 40 mm crown rump length (3 5 to 7 weeks estimated ovulation age) form the basis for the following description (schematically summarized in Fig 2)

Below 5 to 6 mm crown rump length (Fig 2 a) the primitive maxillary artery (a branch of the internal carotid artery probably from its future intracavernous part) supplies the optic vesicle This artery normally dwindles in size after the 5 to 6 mm stage when other more distal internal carotid artery branches have taken over its role of supply in the adult it probably is represented by minor intracavernous branches to the infundibular process

At the 4 to 6 mm stage the dorsal ophthalmic artery appears as a branch originating from the point of division of the internal carotid artery into one cranial and one caudal stem The caudal stem will eventually constitute the posterior communicating artery while the cranial division (the primitive olfactory artery) later will give rise to the anterior choroidal middle cerebral and anterior cerebral arteries (Fig 2 b c)

At the 10 mm stage (Fig 2 b) a primitive ventral ophthalmic artery is also found arising from the cranial stem of the internal carotid artery opposite the origin of the anterior choroidal artery and participating in the supply of the optic cup Following the development of the brain the primitive ventral ophthalmic artery becomes stretched In the 20 mm embryo (Fig 2 d) its branches have been annected by the primitive dorsal ophthalmic artery and it seems to terminate at the cartilage around

the optic nerve At the same stage the primitive dorsal ophthalmic artery has migrated caudally along the carotid artery probably by means of anastomotic loops to form the adult ophthalmic artery

Recently two French authors (LASJAUNIAS 1975 MORET 1975) based on the literature on anatomic dissections of human and canine specimens and on angiography suggest a different embryologic scheme that was designed after comparative embryologic considerations to explain developmental anomalies sometimes found in man According to these authors in the 4 mm embryo (Fig 3 a) the orbit is supplied through two primitive ophthalmic arteries—one ventral originating from the future anterior cerebral artery and one dorsal originating from the intracavernous part of the internal carotid artery The adult ophthalmic artery should then be formed through caudal migration of the primitive ventral ophthalmic artery while the primitive dorsal ophthalmic artery regresses

Discussion

The two embryologic schemes presented differ in many respects They not only suggest different points of origin of the primitive ophthalmic arteries but also a different role for each artery in the formation of the adult ophthalmic artery LASJAUNIAS et coll (1975) presented one case in which the adult ophthalmic artery originated from the anterior cerebral artery and explained this anomaly by postulating that the primitive ventral ophthalmic artery might originate from the anlage of the future anterior cerebral artery (Fig 3 e) This postulation could also readily explain the anomaly presented in the present report as persistance of the primitive ventral ophthalmic artery in conjunction with regression of the proximal part of the anterior cerebral artery (Fig 3 f)

PADGET states that the ventral ophthalmic artery originates more proximal opposite the anterior choroidal artery However in one of her illustrations (PADGET Fig 6) it is seen to arise at the level of an ill defined network that later forms the middle cerebral artery A slightly different way of condensation of this network (Fig 2 b) could explain the anterior cerebral origin of the ophthalmic artery observed by LASJAUNIAS et coll as well as the anomalous vessel presented in this report (Fig 2 g h)

Some other rare anomalies could also be explained by either scheme The ophthalmic artery has been reported to arise from the middle cerebral artery in conjunction with ipsilateral absence of the internal carotid artery (FLEMMING 1895 LOWRY 1916) as well as from the posterior communicating artery in a case with complete absence of both internal carotid arteries (FISHER 1914) Both these anomalous origins could readily be explained as incomplete migration of respectively the primitive ventral (LASJAUNIAS MORET) or primitive dorsal (PADGET) ophthalmic artery (Fig 2 f)

The major difference between the two schemes concerns the origin of the primitive dorsal ophthalmic artery and secondarily the question of which artery that

migrates to form the adult ophthalmic artery Basing their conclusions on comparative embryology LASJAUNIAS and MORET localize the origin of the primitive dorsal ophthalmic artery to the intracavernous part of the internal carotid artery By assuming that the primitive ventral ophthalmic artery normally migrates along the internal carotid artery to form the adult ophthalmic artery these authors could then explain the occasionally observed intracavernous origin of the ophthalmic artery (DILENGE et coll 1965 LOMBARDI 1969) or of one of the stems of a reduplicated ophthalmic artery (POIRIER 1896) as a persistance of the primitive dorsal ophthalmic artery with or without aplasia of the adult stem (Fig 3 c d)

However in all reconstructions presented by PADGET the primitive dorsal ophthalmic artery originates opposite the posterior communicating artery far distal not only to the intracavernous part of the internal carotid artery but also to the adult ophthalmic artery Furthermore in several of her illustrations (PADGET Figs 7 8) an adult ophthalmic artery is found at the same time as a remaining primitive ventral ophthalmic artery while the primitive dorsal ophthalmic artery is hypoplastic (Fig 3 d) These findings could evidently not be used to explain the intracavernous origin of the adult ophthalmic artery *Without rejecting the results of PADGET another explana*tion could be offered The primitive maxillary artery is known to participate in the supply of the optic region in early embryologic life and is supposed to originate from the intracavernous part of the internal carotid artery—persistance of this artery could account for the intracavernous origin of the adult ophthalmic artery

SUMMARY

One case of a rare anomaly of the anterior cerebral artery is presented and possible embryologic explanation to this and other arterial anomalies in the same region is discussed

ZUSAMMENFASSUNG

Ein Fall einer seltenen Anomalie der A cerebralis ant wird beschrieben und die mogliche embryologische Erklarung dieser und anderer arterieller Anomalien derselben Region diskutiert

RESUMÉ

Les auteurs presentent un nouveau cas d une anomalie rare de l artere cerebrale anterieure et examinent les explications embryologiques possibles de cette anomalie et d autres anomalies artérielles dans la meme region

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REPEAT ANGIOGRAPHY IN TEMPORAL CONTUSIONS

S CRONQVIST and U TYLEN

Intracranial lesions following head trauma are generally complex with simultaneously occurring extracerebral and intracerebral components The cerebral component appears as a contusion consisting of macerated brain tissue with oedema and with more or less admixture of haemorrhage sometimes also encircling the injured tissue The site of contusion varies depending upon the strength and the direction of the trauma and multiple contusions may be present The most frequent location of a singular contusion seems to be the temporal region At angiography a temporal contusion is characterized as any other mass lesion in that region i e a medial displacement and elevation of the middle cerebral artery and its Sylvian branches and possibly by a shift of the midline structures The Sylvian vessels have a more or less marked arched course with the concavity directed towards the base of the skull Local circulatory disturbances with delayed emptying of arterial branches or premature venous filling within or adjacent to the contused region are other common findings (LEEDS et coll 1966 CASTRO 1969 GLICKMAN et coll 1971 MANELFE et coll 1973)

The angiographic appearances of a temporal contusion examined in close connection to the trauma tend to be more discreet than might be expected from the clinical symptomatology However more evident abnormalities better reflecting the clinical condition may develop with time A survey of the literature seems to indicate that

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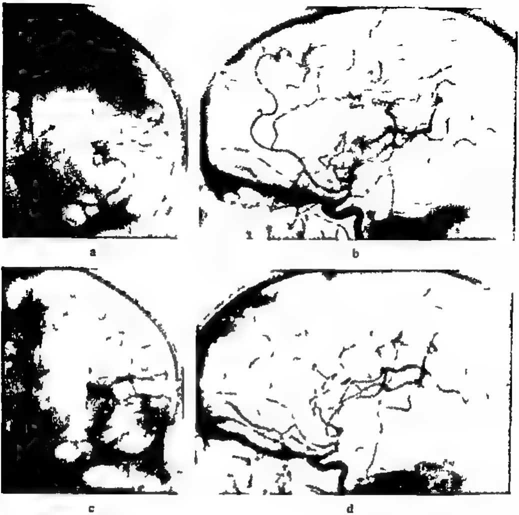


Fig. 1 Temporal contusion a b) Examination on the day of the accident Shift of the midline arteries Medial displacement of the middle cerebral artery and branches which are stretched but only slightly elevated Spasm of the intracranial arteries Small extracerebral haematoma c d) 5 days after the accident No additional displacement of the midline structures Marked increase of the elevation and stretching of the Sylvian arteries The medial displacement of the middle cerebral artery has increased as well Vascular spasm unchanged The extracerebral haematoma has diminished

these facts are not commonly appreciated Since these observations may be of therapeutic importance the films of some of the patients with temporal contusion at this department have been reviewed

Material and Methods

Patients with expanding lesions or local circulatory disturbance in the temporal region at angiography following head trauma were selected Patients with angiographic evidence of lesions also in other regions of the brain were excluded as well

Fig. 2 Large contusion of the left temporal lobe with no evidence of contralateral mass lesion a) No shift of the midline arteries Marked elevation and medial displacement of the middle cerebral artery and Sylvian vessels b) No shift of the internal cerebral vein

those with extracerebral haematoma exceeding a depth of 10 mm 36 patients then remained The first angiography was made within the first 3 days following the accident in 26 patients the remainder was examined within the first week with the exception of one patient examined as late as on the 12th day Bilateral angiography was performed in 8 patients only while in others filling of arteries on both sides were obtained after compression of the contralateral carotid artery

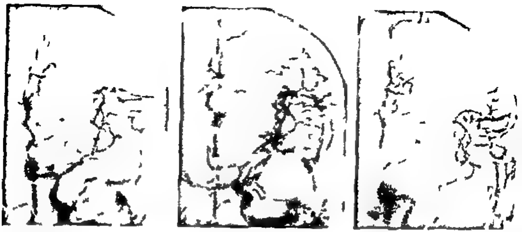
The contrast medium was injected into the common carotid artery and the film series was exposed in the a p lateral and oblique projections

Following the angiography 15 patients were operated upon with removal of contused brain tissue or with a temporal lobe resection In 7 patients the clinical signs did not warrant an acute operation these were treated conservatively and subsequently improved Fourteen additional patients with signs not indicating acute operation either did not improve or their clinical condition deteriorated A second angiography was therefore carried out within two weeks after the accident in all but two patients who were examined on the 25th and 39th day respectively Following this second angiography 6 patients were operated upon with a temporal lobe resection A third angiography was performed in 4 of the remaining 8 patients on the 11th 12th 43rd and 45th day after trauma respectively None of these patients was operated upon

Three of the 36 patients in this series died all operated upon in the acute stage

Results

At the first angiography an expanding lesion in the temporal lobe was demonstrated in all patients In addition circulatory disturbance was evident in 9 cases



a b c

Fig. 3 Left temporal lobe contusion a) 7 days after the accident Shift to the right of the midline arteries Medial displacement and elevation of middle cerebral artery and Sylvian vessels b) 16 days after the accident Midline shift unchanged Increase of displacement of middle cerebral artery c) 45 days after the accident Still slight shift to the right of the midline structures Decrease of displacement of middle cerebral artery

early filling of veins in 6 cases and delayed passage through local arteries in 3 Generalized arterial spasm was found in 3 patients (Fig 1) and bilateral mass lesions in 2 Based upon the degree of vascular displacement the lesions were considered as small in 9 medium sized in 16 and large in 13 cases Proportionate displacement upwards and medially of the Sylvian vessels was evident in 18 cases Predominantly upward displacement of the middle cerebral artery was present in 8 cases and predominantly medial displacement in 12 In some of the patients there was a definite discrepancy between the shift of the midline structure and the estimated size of the temporal mass Thus despite the presence of a medium sized or large temporal lesion 6 patients had only a minimal or no shift at all of the pericallosal artery or the internal cerebral vein (Fig 2) In 2 of these 6 cases a contralateral lesion smaller in size was also present

Among the 14 patients in which repeat angiography was performed a small lesion was evident in 7 a medium sized in 4 and a large in 3 cases respectively Compared with the first angiography no significant change had occurred in 2 both with a small initial lesion In 3 patients the mass lesion had decreased in size the repeat angiography was performed 12 25 and 39 days after the trauma respectively Increase in size of the temporal expansivity—as estimated by increasing vascular displacement—occurred in 9 patients (Figs 1 3) In 8 of the 9 cases the second angiography was performed within one week after the trauma in the ninth case as late as on the 14th day

A third angiography was performed in 4 of the patients in whom the second one had demonstrated increase in size of the lesion In 2 examined on the 11th and the 12th day respectively the lesion was unchanged in 2 examined on the 43rd and 45th day respectively the lesion had decreased in size (Fig 3)

Discussion

In patients with only a slight decrease of the level of consciousness with few neurologic signs no abnormality or only a small temporal expanding lesion at angiography is the rule (LEGRE et coll 1969) In some of these patients a further decrease in the level of consciousness may occur Such a development corresponds to swelling of the injured brain tissue The maximum swelling usually occurs between the third and seventh day (LINDGREN 1960 MCLAURIN & HELMER 1965) The cause of this late swelling of the contused brain tissue is not fully understood It is most probably due to an increase of the oedema within and surrounding the contusion. This opinion is supported by the fact that an interval between bleeding and maximum swelling demonstrated at angiography also has been reported in cases with intracerebral haemorrhage (YAMAGUCHI et coll 1973)

An increase in the size of the contusion was evident in 9 of the present 14 patients in which repeat angiography was performed Most of these were examined within the first week i e at the time at which maximum swelling of the ischaemic brain tissue occurs

The two patients with stationary conditions had very small lesions and those in whom decrease was demonstrated were examined late in the course of the disease

An angiographic finding of specific importance is the discrepancy between the shift of the midline structures and the estimated increase of the volume of the contused temporal lobe There may in fact be no shift whatsoever of the pericallosal artery or the internal cerebral veins despite presence of a large temporal expanding lesion in cases with one sided lesion only This was demonstrated in 4 cases (Fig 2) all operated upon immediately after the angiography This fact may be due to a delay in the effect on the midline structures (COLUMELLA et coll 1963 HEISKANEN & VAPALAHTI 1972)

In the absence of evidence of mass lesion on one side as indicated by a shift of the midline structures the detection of small temporal lesions with a minimum displacement of the middle cerebral artery may be facilitated by comparison between the position of these arteries on the two sides To a certain extent evaluation of the contralateral side is possible on a p films after compression of the contralateral carotid artery Significant temporal contusion and also extracerebral haematomas may thus easily be diagnosed However local circulatory disturbance is not easily appreciated on a p films Series taken in the lateral projection should be preferred and for this reason bilateral angiography is recommended in cases with traumatic lesions

SUMMARY

In the diagnosis of a temporal contusion bilateral filling of the Sylvian vessels permits adequate comparison between the two sides Such a comparison is important since even at a large contusion with marked upward or medial displacement of the Sylvian vessels no

corresponding shift of the midline structure may exist in the acute stage With increasing interval between trauma and angiography a shift may develop reflecting the true size of the lesion

ZUSAMMENFASSUNG

Bei der Diagnose einer temporalen Kontusion erlaubt die bilaterale Fullung der Gefasse in der Fissura Sylvii einen adaquaten Vergleich zwischen den beiden Seiten Ein derartiger Vergleich ist wesentlich da selbst bei einer umfangreichen Kontusion mit einer starken Verlagerung nach oben oder in medialer Richtung der Gefasse in der Fissura Sylvii keine entsprechende Verschiebung der Mittellinie Strukturen im akuten Stadium vorzuliegen brauchen Mit steigendem Intervall zwischen Trauma und Angiographie kann eine Veränderung geschehen, die die wirkliche Grosse der Lasion wiedergibt

RESUME

Dans le diagnostic d une contusion temporale l examen des vaisseaux sylviens d cotés permet une comparaison adéquate entre les 2 cotes Cette comparaison est importante car au stage aigu il peut y avoir une volumineuse contusion avec un déplacement important en haut et en dedans des vaisseaux sylviens sans deplacement correspondant des structures de la ligne médiane A mesure que l intervalle entre le traumatisme et l angiographie augmente un déplacement de la ligne médiane peut apparaitre représentant la véritable dimension de cette lésion

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ANGIOGRAPHY OF THE TESTICULAR ARTERY

II Cryptorchism and testicular agenesis

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When one or both testicles are absent from the scrotum it is either a question of cryptorchism or of testicular agenesis A differential diagnosis is important for several reasons The incidence of malignant tumour is reported to be high in cryptorchid testes according to GILBERT & HAMILTON (1940) it is 48 times and to WHITAKER (1970) 35 times higher than in normally descended testes Cryptorchid testes are furthermore often subject to trauma or torsion (LOWSLEY & CURTIS 1940) And finally there is a good chance that if an early orchiopexy is performed the spermatogenesis will be normal which will not be the case if the testis is allowed to remain in the inguinal canal or in the abdomen (GROSS & JEWETT 1956) After angiography of the testicular artery had proved to be a relatively simple method of examination (NORDMARK 1977) a number of cases have been investigated to ascertain whether this procedure can be used to differentiate between cryptorchism and agenesis and in cases of cryptorchism to localize the testis

Historical notes

The term testicular agenesis means in the strict sense that the primordium of the testis has failed to appear In the present report however testicular agenesis is used to imply congenital absence of testis tissue which may be due either to the fact that

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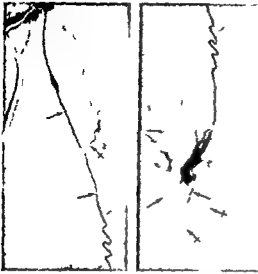
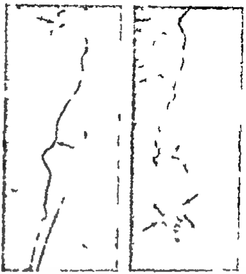


a Fig. 1 b



a Fig. 2 b

Fig. 1. Boy aged 13. Cryptorchism. Selective angiography. Subtraction. a) Left testicular artery (→) runs an ordinary course and the small branches from the central part of the vessel are evident. A lateral branch (↔) runs to the retroperitoneal space caudal to the kidney. b) The testicular artery runs to a testicle (→) situated *medially and dorsally in relation to the internal inguinal ring*. A few vessels run down into the inguinal canal (↔).

Fig. 2. Boy aged 10. Cryptorchism. Selective angiography. Subtraction. a) Right testicular artery (→) is relatively slender and lies farther medially than usual. From the central part, a large number of very slender branches are given off, among others a communicant to an additional testicular artery (↔) from which the lateral branches arise. b) Right testicle (→) is positioned with the upper pole pointing caudally.

the testicular rudiment has not developed or that the testis has become totally atrophied during embryonic development. If one of the testicles is absent the condition is referred to as monorchism and if both are absent in an individual otherwise regarded as a male, the term anorchism is used. According to GOLDBERG et coll. (1974), monorchism is present in 1/5 000 men and anorchism in 1/20 000 men. Only 80 cases of anorchism have been reported according to these authors. Cryptorchism signifies a concealed testicle and may exist either as testicular retention or as an ectopic testis. In the former case, the testicle has become arrested somewhere along the path it normally follows in its passage down into the scrotum during embryonic development and in the latter case it has followed a wrong route. The incidence of cryptorchism in 4-year old Swedish boys is 0.9 per cent (KÖHLER 1973).

Patients with anorchism usually have infantile external genitals and the general appearance of a eunuch. They deviate from the normal population with respect to the hormonal pattern and it is considered that the condition can be established by hormone analysis alone (BABLOK et coll. 1974). In the case of monorchism and cryptorchism, on the other hand, neither appearance nor hormone pattern deviate from the normal.

Various radiologic methods have been tried for the demonstration of cryptorchism and testicular agenesis LUNDERQUIST & RAFSTEDT (1967 1968) reported having used pneumoperitoneum with the head-end lowered in the examination of 60 patients ranging in age from 0 to 15 years Views were obtained with the patient prone and the head lowered 40 to 45 degrees The examination was carried out in order to distinguish between retained and ectopic testicles None of the patients had agenesis and no complications occurred

A water soluble contrast medium may be injected into the abdominal cavity instead of gas The patient is then examined in the prone position with the foot end lowered The examination is referred to as herniography as it is used mainly for the demonstration of inguinal hernia Cryptorchid testes located in the pelvis minor may be demonstrated The method has been described by DWOSKIN & KUHN (1973)

JACOBS (1969) used selective gonadal phlebography in 28 patients 2 with anorchism and one with cryptorchism The examination was performed to facilitate a selective hormone analysis of blood from the testicular or ovarian vein respectively After puncturing of the femoral vein in the groin the testicular or ovarian vein was catheterized the catheter being passed down without difficulty to the level of L5 With the catheter in this position 15 to 20 ml meglumine iothalamate (Conray 60 Mallinckrodt) were injected within 10 seconds In the male patients the pampiniform plexus filled in those cases in which a testis was present In patients with agenesis the vein ended in a blind alley The result of the examination was confirmed at operation No serious complications were reported

Angiography of the testicular artery for localization of cryptorchid testes has also been reported KOISCHWITZ (1973) described a case with a malignant teratoma in a cryptorchid testis which was diagnosed by among other measures selective nephroangiography on the left side The left testicular artery which arose from the left renal artery filled with contrast medium and was supplying a large vascularized tumour at the level of the sacroiliac joint

BEN MENACHEM et coll (1974) described a case of bilateral cryptorchism in an adult male At the preliminary aortography the testicular artery was identified on both sides and could then be examined selectively allowing both testicles to be localized They proved to be slightly smaller than normal The right testicle lay in the lower part of the abdomen cranial to the pelvic inlet and the left one was located near the internal inguinal ring The angiographic observations were confirmed at operation Microscopy revealed atrophy and hypoplasia of both testes the epididymis was normal in appearance on both sides

VITALE et coll in 1974 reported on 5 adult patients with cryptorchid testes detected by selective angiography of the testicular artery The angiographic findings were confirmed at operation The testicle was in 4 cases located at the internal inguinal ring and in the fifth at the level of S2 It is not known whether microscopic examination of the testicles was carried out

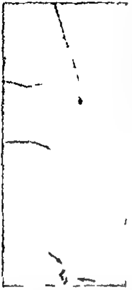
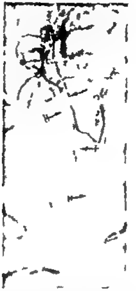
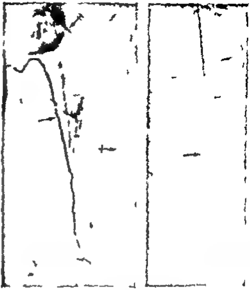




Fig 3 Fig 4 a Fig 5 b

Fig 3 Boy aged 8 Cryptorchism Selective angiography Subtraction Left testicular artery is visible down to the testis in the inguinal canal (→)

Fig 4 Boy aged 14 Testicular agenesis Selective angiography Subtraction Left testicular artery (→) into which the contrast medium was injected gives off the lateral branches as well as a communicant (↔) to another testicular artery (↠) which passes down in the usual way toward the pelvis minor A lumbar artery (o→) has been filled through small branches from the central part of the testicular artery

Fig 5 Boy aged 12 Testicular agenesis Selective angiography Subtraction a) Left testicular artery (→) A vessel from the lateral branch (↔) runs to the fatty capsule of the kidney The small branches from the central part of the testicular artery are evident A branch to the left renal artery (←) has been filled through a communicant b) The left testicular artery (→) can be followed to the inguinal canal where it passes directly over into a vein with no vascular plexus in between

Material and Method

The material in the present report consisted of 14 patients 7 boys between 8 and 14 years of age and 7 men 19 to 55 years old At the clinical examination the left testicle was absent in 13 patients and the right in one case

Selective angiography of the testicular artery using the method described by NORDMARK was performed in all cases on the side on which the testicle had not been palpated Twelve patients were subjected to operation In those who had proved at the angiography to have testicular agenesis or atrophy the inguinal canal and retroperitoneal space to the level of the hilum of the kidney were exposed The gonadal vessels as well as all adjoining structures bearing a resemblance to a gonad or a gland were excised The material obtained was embedded in paraffin sectioned and stained with haematoxylin-eosin or the van Gieson stain and thoroughly examined in a light microscope by one and the same pathologist Orchiopexy or orchiectomy was performed in the patients with abnormally situated testicles

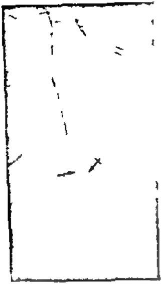


Fig 6

Fig 7

Fig. 6 Boy aged 11 Testicular agenesis Selective angiography Subtraction Left testicular artery (→) can be followed to the internal inguinal ring where it passes directly over into a vein without a plexus Lateral branch (↦)

Fig 7 Man aged 41 Cryptorchism Selective angiography Subtraction Left testicular artery runs to a testicle (→) in the inguinal canal

Results

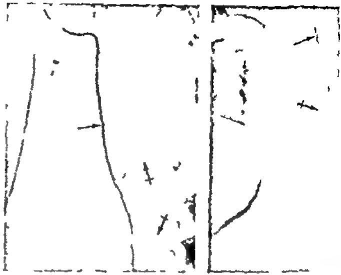
Of the 14 patients in the material 4 had cryptorchism One case had previously been treated surgically for cryptorchism but the testicle had later moved back into the inguinal canal The other 3 patients had not previously been operated upon for this defect Selective angiography could be performed in all 4 cases The cryptorchid testis was slightly smaller than normal in all of them

Angiography demonstrated the testis in the inguinal canal in the case previously operated upon (Fig 7) and medial to the inguinal canal in one case (Fig 1 b) in one case it was considered to lie in the inguinal canal but with the upper pole pointing caudally (Fig 2 b) and in one case close to the external inguinal ring (Fig 3) The findings were confirmed at operation except in the third case where the testis proved to be situated caudal to and in front of the inguinal canal

In the other 10 patients the angiographic appearances were considered to indicate unilateral agenesis of the testis or in one case advanced atrophy (Fig [illegible] b) A selective examination could be carried out in all [illegible] cases

The testicular artery passed in most cases directly into a vein without a vascular plexus in between This vein followed the artery in a cranial direction It ended at the level of the sacroiliac joint in 2 patients laterally in the pelvis minor in 2 at the internal inguinal ring in 4 and at the external inguinal ring in 2 patients The final part of the artery was very slender except in one case (Fig 8) in which the terminating branch was tortuous and in another case (Fig 9 b) in which the vessel ended in a small ball of vessels In one case (Fig 11 b) the testicular artery was relatively wide all the way to its abrupt termination in the inguinal canal

Fig 8



a Fig 9 b

Fig 8 Man aged 40 Testicular agenesis Selective angiography Subtraction Left testicular artery divides into a lateral branch (→) and an end branch (↔) which is unusually tortuous and ends at the level of the sacroiliac joint

Fig 9 Man aged 22 Testicular agenesis Selective angiography Subtraction a) Left testicular artery (→) gives off two well-developed lateral branches (↔) b) The artery (→) ends in a vascular plexus (↔) laterally in the pelvis minor

All but two patients were operated upon and the angiographic diagnosis of testis agenesis was confirmed The epididymis was demonstrated at microscopy in 2 and the ductus deferens identified in 5 patients

The total duration of the fluoroscopy was recorded in half the patients being 10 minutes on the average (range 4 to 21 1 2 min) In most of the patients with cryptorchism and in those with the testicular artery demonstrated at aortography (6 cases) it was slightly shorter

All patients examined by selective testicular angiography were questioned thoroughly about their sensations during the injection of the contrast medium and as to where they had felt discomfort Among those with a testis in the scrotum only slight pain usually in the lumbar region was reported some felt discomfort in the lower part of the abdomen and one or two in the scrotum The younger patients experienced more pain than the older ones some of whom felt nothing at all Among the patients with agenesis some experienced such severe pain that they could not lie still even though the amount of contrast medium injected was as low as 1 ml In the patients with agenesis the pain was located in the back or in the lower part of the abdomen in an approximately equal number of cases The pain began to subside as soon as the catheter had been removed from the vascular orifice and in most cases it disappeared within half a minute

Fig 10

a Fig 11 b

Fig 12

Fig 10 Man aged 19 Testicular agenesis Selective angiography Subtraction Left testicular artery (→) is slender and lies farther medially than usual ventral to the vertebral bodies No branches are filled except toward the midline

Fig 11 Man aged 55 Testicular agenesis Selective angiography Subtraction a) Left testicular artery (→) Lateral branch (↠) b) The artery ends abruptly in the inguinal canal (→)

Fig 12 Man aged 27 Testicular agenesis Selective angiography Left testicular artery (→) with an end branch (↠) and a lateral branch (↠)

With the exception of the pain experienced during the injection no complications occurred during or as a result of the angiography

The diameter of the testicular artery was measured with a vernier calliper If the diameter was measured on a film exposed at a selective injection the figure was higher than on a film from an aortography sometimes 2 to 3 times higher The width of the artery was unchanged from its origin to the point where it gave off a branch of some size The artery was visible at aortography in 3 of the 4 patients with cryptorchism but it was narrower than on the normal side In 2 of the boys the width on the normal side was measured as being 1 5 mm and in one case as 1 0 mm In the two older boys the width was 0 7 mm on the cryptorchid side

Among the 10 patients with agenesis the relevant testicular artery was demonstrated at aortography in 3 instances its width being measured as approximately 1 0 mm (0 8 mm to 1 2 mm) In a fourth patient the artery could be distinguished on the film retrospectively the diameter then being measured as 0 3 mm After the selective injection of contrast medium the figure for the diameter increased by half as much again except in one case in which it was 3 times higher (increased from 0 3 mm to 0 9 mm) In the 6 patients in whom no testicular artery was demonstrated at aortography the width at the selective examination was between 0 8 mm and 1 4 mm

The testicular artery gives off a number of branches which are clearly distinguishable in cases with testis agenesis and when the artery is examined selectively

Within the first few centimeters close to the origin of the artery in the aorta a large number of very slender vessels branch off to the immediate surroundings (Figs 1 a, 5 a). Among these branches there may also be communicating vessels running to other possibly present testicular arteries (Fig 2 a) or to a lumbar artery (Fig 4) or renal artery (Fig 5 a). From this part of the testicular artery also a branch sometimes runs to the adrenal gland as well as small branches to the hilum of the kidney. Approximately at the level of L3 a relatively large branch often runs to the retroperitoneal space between the iliac crest and the caudal pole of the kidney (Figs 1 a, 4, 12). This branch sometimes arises slightly farther toward the caudal aspect (Figs 6, 8, 11 a) and both branches may be clearly demonstrated (Fig 9 a). A couple of vessels run from one of these two lateral branches to the fatty capsule of the kidney (Fig 5 a). Narrow branches arising at different points run to the ureter, sometimes near the hilum of the kidney or the urinary bladder but usually in the middle segment of the ureter.

Discussion

Angiography of the testicular artery has proved valuable for localization of a cryptorchid testis and for the demonstration of testis agenesis. The methods hitherto used, pneumoperitoneum (andrography, LUNDERQUIST & RAFSTEDT 1967) and herniography (DWOSKIN & KUHN), seem to be useful risk free procedures when the patient has a cryptorchid testis in the small pelvis or the inguinal canal, but they cannot provide definite information regarding agenesis. Phlebography of the testicular vein seems to give greater certainty than pneumoperitoneum and herniography (JACOBS) for diagnosing agenesis, but the material reported is too small to permit a conclusive evaluation of the method.

The present series of patients with cryptorchism or unilateral testis agenesis were examined by angiography of the testicular artery. The angiography could be carried through in all cases with no complications except for transient pain during the injection of the contrast medium in the patients with agenesis.

KAHN & FRATES (1968) stated that among cases in which the testicular artery was not visible at aortography the selective examination could be performed successfully in only 20 per cent, but the present series demonstrates that selective testicular angiography can be carried out in a much higher percentage of cases. Among the 14 patients, the testicular artery was not visible at aortography in 8. The selective procedure nevertheless could be performed in all patients without any unacceptable prolongation of the total fluoroscopic time.

The testis was demonstrated clearly in the patients with cryptorchism, and its position could be established with sufficient exactness for surgical purposes.

In the agenesis patients the diagnosis was unequivocal and was confirmed at operation and at the subsequent microscopy. In one case (Fig 9 b) the angiography suggested an atrophic testis, but no gonadal tissue could be found at microscopy. In 2 cases, an epididymis was identified at microscopy, but these cases did not

differ roentgenologically from the other agenesis cases The relatively large end branch in one case (Fig 11 b) is interesting the probable explanation is torsion at an early stage possibly during intra uterine development with subsequent total testicular atrophy This hypothesis is consistent with the view previously advanced as a possible explanation of testicular atrophy (GOLDBERG et coll) These authors presented a material consisting of 9 cases of anorchism and 39 of monorchism The testicular artery was not identified at operation in 5 of the patients with anorchism and in 20 of those with monorchism It is to be doubted however whether the artery really was absent *an angiography was not performed and a testicular artery* of the type illustrated in Fig 8 for instance could well have been present

NOTKOVICH (1955) stated that branches run from the testicular artery to the adrenal gland the ureter the perirenal fat and tissues in the immediate vicinity of the artery No branches from the artery are demonstrated at an aortography performed with the currently used technique The branches are usually very slender in patients with a normal testicle in the scrotum but they are nevertheless fully visible when the artery is examined selectively In the present series of cryptorchism and agenesis cases these branches stand out very differently The lateral branches are the most conspicuous and are also those most frequently observed A testicular artery practically without any branches is illustrated in Fig 10 The probable explanation is that another testicular artery is present which gives off the missing branches (cf Fig 2 a) In one case (Fig 4) the contrast medium was injected into the testicular artery with the lateral branches

The veins followed the arteries except in the parts located farthest in toward the centre These veins probably constitute some of the communicating vessels mentioned by AHLBERG et coll (1966) and JACOBS According to the description of these vessels they are in good agreement with the lateral branches Some of these communicants thus ought instead to be regarded as ordinary branches to the testicular vein If conclusive information is desired regarding whether a given vein observed at phlebography is a branch to the testicular vein or a communicating vessel a selective angiography of the testicular artery must be performed

SUMMARY

A selective angiography of the testicular artery was performed in 7 boys and 7 men without a palpable testicle in order to localize cryptorchid testes or to establish testicular agenesis The examination could be carried out in all cases and the angiographic diagnosis was confirmed at operation and at a subsequent microscopy in the 12 cases hitherto operated upon The width of the artery and its branches are also presented

ZUSAMMENFASSUNG

Eine selektive Angiographie der A testicularis wurde bei 7 Jungen und 7 Mannern ohne palpable Testikeln ausgefuhrt um die kryptorchen Hoden festzustellen Die Untersuchung

konnte bei allen Fallen ausgefuhrt werden und die angiographische Diagnose wurde bei der Operation sowie durch die nachfolgende Mikroskopie bei 12 bisher operierten Fallen bestatigt Es wird die Weite der Arterie und deren Zweige ebenfalls gegeben.

RESUME

Les auteurs ont fait une angiographie selective de l artere testiculaire chez 7 garçons et 7 hommes qui n avaient pas de testicules palpables pour localiser les testicules cryptorchides ou pour etablir l agenesie testiculaire Cet examen etait possible dans tous les cas et le diagnostic angiographique a ete confirme a l operation et par l examen microscopique dans les 12 cas qui ont ete operes chirurgicalement jusqu a maintenant Les auteurs decrivent aussi le calibre de l artere et de ses branches

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FROM THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY AND UROLOGY THE NORWEGIAN RADIUM HOSPITAL OSLO NORWAY

PHLEBOGRAPHY, UROGRAPHY AND LYMPHOGRAPHY IN THE DIAGNOSIS OF METASTASES FROM TESTICULAR TUMORS

H H LIEN and A KOLBENSTVEDT

The prognosis of patients with testicular tumors depends on the microscopic appearance of the tumor and the stage of the disease WILKINSON & MACDONALD (1975) reported an overall three year crude survival rate of 94 per cent in stage I irrespective of microscopy compared with 64 per cent in stage II with lymphographic evidence of metastases below the diaphragm The corresponding figures for non seminomas were 90 and 41 per cent respectively Assessment of the presence and extent of metastatic growth is essential in both prognosis and treatment and must be mainly based on radiologic examinations The effect of radiation therapy and chemotherapy may also be evaluated by repeated radiography

The regional lymph nodes of the testes are located on the ipsilateral side of the lumbar vertebral column somewhat more distal on the right than on the left side (CHIAPPA et coll 1966) A crossover of testicular lymphatics to the contralateral lumbar nodes also occurs (BUSCH et coll 1965)

At this hospital cavography and urography have been routinely used in the search for retroperitoneal metastases since 1957 foot lymphography since 1970

MAHAFFEY (1964) and HOPF & FUCHS (1970) considered lymphography and cavography to be complementary procedures As left lumbar metastases must have reached a considerable size to produce distortion of the inferior vena cava they are dem

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konnte bei allen Fällen ausgeführt werden und die angiographische Diagnose wurde bei der Operation sowie durch die nachfolgende Mikroskopie bei 12 bisher operierten Fällen bestätigt. Es wird die Weite der Arterie und deren Zweige ebenfalls gegeben.

RESUME

Les auteurs ont fait une angiographie sélective de l'artere testiculaire chez 7 garçons et 7 hommes qui n'avaient pas de testicules palpables pour localiser les testicules cryptorchides ou pour établir l'agenesie testiculaire. Cet examen était possible dans tous les cas et le diagnostic angiographique a été confirmé à l'opération et par l'examen microscopique dans les 12 cas qui ont été opéres chirurgicalement jusqu'à maintenant. Les auteurs décrivent aussi le calibre de l'artère et de ses branches.

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Table 1

Retroperitoneal metastases in relation to microscopy of primary tumor

Diagnosis	No of patients	No of patients with metastases
Seminoma	63	16
Embryonal carcinoma	32	16
Teratoma	21	6
Choriocarcinoma	1	1
Lymphosarcoma	1	—
Endodermal sinus tumor	2	—
Total	1 0	39

phlebography to be helpful in defining retroperitoneal and pelvic pathology Extensive investigations of the renal and gonadal veins were also performed by AHLBERG et coll (1965 1966 1968) and CHIDEKEL (1968) No report seems to have been published on phlebography of the renal and testicular veins in a large number of patients with testicular tumors This motivated an assessment of the value of a combination of the radiologic examinations mentioned with special emphasis on the left renal and testicular veins

Material

During the period November 1973 to November 1975 a total of 152 patients with tumor of the testis was admitted Because of impaired pulmonary function advanced disease or extensive allergy 32 patients were not submitted to complete lymphography and phlebography These were therefore excluded from the material which thus consisted of 120 patients 64 with primary tumor in the right and 55 in the left testis One patient with microscopically confirmed retroperitoneal metastasis from choriocarcinoma was not subjected to orchidectomy because of bilateral testicular atrophy without palpable primary tumor

Five of the 120 patients were aged between 10 and 19 67 between 20 and 39 43 between 40 and 59 and 5 patients were more than 60 years old The microscopic classification (MILLER & SELJELID 1971) was as follows Seminoma 63 embryonal carcinoma 32 teratoma 21 choriocarcinoma 1 lymphosarcoma 1 In addition 2 patients had endodermal sinus tumor

Methods

After preliminary radiography of the chest and abdomen lymphography was performed by injecting Lipiodol Ultra Fluid into a lymph vessel of each foot Further details of the technique and radiographic procedures are given previously (KOL

Table 3

Side localization of retroperitoneal metastases

Primary tumor	Metastases			
	Right side	Left side	Bilateral	Total
Right testicle	6	1	10	17
Left testicle	1	[illegible]	11	21
Uncertain localization			1	1
Total	7	10	22	39

lowing treatment in the other) and by phlebography of the left testicular vein in 2 (both confirmed by normalization following treatment) These 2 patients had a deviation of the left testicular vein as the only sign indicating retroperitoneal involvement (Fig 3)

The side localization of metastases from primary tumors of the right and left testicles respectively is given in Table 3

Pulmonary or mediastinal metastases were evident in 14 of the 39 patients with retroperitoneal growth (8 with embryonal carcinoma 3 teratoma 2 seminoma and 1 choriocarcinoma) In addition 4 patients with normal radiologic findings of the retroperitoneal space had pulmonary metastases All of these had embryonal carcinomas

Discussion

The results support the view that lymphography cavography and urography are complementary procedures (MAHAFFEY HOPF & FUCHS) The value of phlebography of the left renal vein (COPE & ISARD) and of gonadal phlebography (JACOBS) in the search for retroperitoneal malignant growth was also confirmed Phlebography of the renal and testicular veins revealed metastases in 31 of the 39 patients with demonstrable retroperitoneal growth even though these examinations only cover the upper lumbar region mainly on the left side The corresponding number for lymphography from the foot in this region was 30 The additional phlebographic examinations were of particular value in assessing the extent of metastatic tumor masses (Figs 2 4) and as a supplement when the lymphographic findings were uncertain They were also useful in the search for recurrence (Fig 5)

Although lymphography never was the only examination indicating metastasis it was more frequently abnormal than any of the phlebographic procedures Lymphography also covers more regions and may for example reveal metastases along the thoracic duct and in the supraclavicular region

The frequent occurrence of bilateral metastases (Table 3) indicates that phlebography of the left renal and testicular veins should be performed regardless whether the primary tumor is located in the left or the right testis

a b

Fig 5 Embryonal carcinoma of the left testis Phlebography of the left renal vein Lymphography on admission suggested metastasis on left side at lower part of third lumbar vertebra a) On admission Left renal vein runs an oblique course but no abnormalities are evident. b) Repeat examination 2 years later after chemotherapy and laparotomy with removal of metastatic glands (clips) Indentation of left renal vein (→) deviation and stenosis of the left ureter suggest recurrence of metastatic growth (confirmed by later progression)

Although the pathologic findings in the present series have been established beyond reasonable doubt by repeat examinations the true frequency of retroperitoneal metastatic spread cannot be given The presence of microscopic metastases can only be assessed by complete microscopy of all retroperitoneal nodes Surgery was not included in the treatment routine which consisted of irradiation of the lumbar and ipsilateral iliac nodes in all patients without demonstrable metastases If retroperitoneal metastases were found additional irradiation was given to the mediastinum and the supraclavicular region on the side of the terminal part of the thoracic duct Chemotherapy was administered to patients with advanced disease

Metastases also including pulmonary or mediastinal metastases were found in 63 (41) of the 152 patients admitted with tumor of the testis Although direct comparison cannot be made due to selection this corresponds well with the figures given by WILKINSON & MACDONALD who in a series of 260 patients with testicular tumors found demonstrable metastases in 110 (42%) These patients were examined by lymphography from the foot occasionally supplemented by cavography and urography but no mention is made of further phlebographic procedures Although only 2 patients in the present series had their metastases revealed solely by phlebography of the renal and testicular veins it is felt that the latter examinations contribute greatly to a more accurate evaluation of metastatic growth in the left lumbar region

SUMMARY

The value of lymphography from the foot urography and phlebography of the inferior vena cava and the left renal and testicular veins in the search for retroperitoneal metastases was investigated in 120 patients with testicular tumors Phlebography of the left renal and testicular veins was a valuable supplement to the other examinations so that the combined use of all these methods is recommended in demonstrating metastases and in evaluating the extent of growth and effect of treatment

ZUSAMMENFASSUNG

Der Wert der Lymphographie der Urographie und der Phlebographie der Vena cava inferior der linken Nierenvene und der Hodenvenen wurde zum Nachweis retroperitonealer Metastasen bei 120 Patienten mit Hodentumoren untersucht Die Phlebographie der linken Nierenvene und der Hodenvenen erwies sich als brauchbares Komplement zu den anderen Untersuchungen Die kombinierte Verwendung aller dieser Methoden zum Nachweis von Metastasen und zur Feststellung der Ausbreitung des Tumors und des Effektes der Behandlung wird empfohlen

RESUME

Les auteurs ont etudie sur 120 malades atteints de tumeur du testicule l intérêt de la lymphographie du membre inférieur de l urographie et de la phlébographie de la veine cave inferieure de la veine rénale gauche et des veines testiculaires dans la recherche de metastases retroperitonéales La phlebographie de la veine rénale gauche et des veines testiculaires est un complement intéressant des autres examens de sorte que l utilisation associée de toutes ces méthodes est recommandee pour rechercher les métastases pour apprécier l étendue de la tumeur et l effet du traitement

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Book review

ATLAS OF ANGIOGRAPHY Edited by K E Loose and R J A M van Dongen 435 pages 707 illustrations G Thieme Verlag Stuttgart 1976 Price DM 190 —

The advertisement of this book states that the aim of the atlas is to provide a guide for all clinicians that have contact with any facet of angiography The editor s intentions are to present visual information of angiograms in a systematic and easily accessible form Angiograms from different regions of the body are presented in eight chapters phlebography and lymphography in one chapter each International authorities are responsible for the different sections which consequently gives varying quality both regarding reproductions of and comments on the films The original idea of systematic presentation of all fields of angiography is not consistent Some fields are missing (thoracic aortography pulmonary angiography) and some are according to this reviewer s opinion underrepresented (abdominal angiography) while peripheral angiography and lumbar aortography are given a dominating space of 134 pages One chapter on supraaortic branches and cerebral arteries deals to a large extent with intracerebral lesions Considering the fact that neuroradiology now is an established subspeciality of radiology and that excellent textbooks in this field offer better coverage of cerebral angiography it seems unnecessary to have this part included

The idea of having case history indications and the radiographic report coupled with one or two angiograms on one page provides an excellent opportunity for analysing angiographic pathology However the presentations are not consistently good even if most of the reproductions are of excellent quality

This method of presentation leaves a lot of empty space on almost every page These wide empty spaces could have been used more systematically and effectively for more detailed case reports and comments on catheter technique injection rate contrast medium used and also pertinent references to many of the interesting illustrations At the end of each chapter references are presented but in several of these the most recent reports are missing In the chapter on cerebral angiography the most recent reference is more than 10 years old

The reproductions of the films are as a rule of excellent quality and a great many are included in this work but it is the reviewer s opinion that most information presented in this atlas can be found in recent textbooks and radiologic journals However some chapters are of high quality and sum up all recent knowledge in their respective fields To these belong the chapters on catheterization technique coronary angiography and lymphography which are worthy of careful perusal

Erik Boijsen

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RETENTION OF WATER-SOLUBLE CONTRAST MEDIUM IN THE URINARY AND GENITAL TRACTS

G THEANDER and L WEHLIN

Retention of urographic contrast medium in the ureter and renal pelvis above an obstructing calculus is a well known phenomenon often utilized in the detection and location of the stone The duration of the retention does not appear to have been systematically analysed but general experience with urography and retrograde pyelography have appeared sufficient to establish a widely held opinion that the walls of the urinary outflow tract provide an efficient barrier to the contrast medium used

MARSHALL et coll (1969) criticized this opinion which they considered merely intuitive and questioned the existence of such a barrier At the same time they reported preliminary experiments in dogs suggesting that the barrier is not as complete as formerly assumed After further experiments with dogs MARSHALL & CASTELLINO (1970) arrived at the conclusion that during retrograde pyelography the pelvicalyceal region is the main site of systemic absorption and that absorption across the ureter is negligible

Occasional observations in patients documenting prolonged retention of water soluble contrast medium in the urinary tract may help to shed light on the mural properties of these pathways in man Three such cases are now reported and an additional case illustrates similar retention in the male genital tract

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Fig. 1 Case 1 a) Urography during pain Delayed excretion of contrast medium and dilatation above calculus at right pelvo-ureteric junction b) Conventional film 8 days later Contrast medium retained above persistent calculus

Case reports

Case 1 A man aged 42 years and known to have a calculus in a calyx of the right kidney was referred because of a sudden attack of right-sided renal colic Urography with 20 ml of Isopaque 350 revealed that the stone had moved spontaneously and was now lodged at the junction between the right renal pelvis and the ureter (Fig. 1 a) On that side the excretion of contrast medium was markedly delayed the nephrographic effect persisted throughout the examination and the renal pelvis was dilated Conventional films of the abdomen 4 and 8 days later still demonstrated persistence of the stone at the pelvo-ureteric junction (Fig. 1 b) On both occasions persistent dilatation of the right renal pelvis was demonstrated by contrast medium retained above the stone pyelolithotomy was performed the following day

Case 2 A man aged 30 years had two attacks of right-sided renal colic at an 8 month interval without pain Urography was performed with 20 ml of Isopaque 350 on both occasions and revealed a stone 2 mm across in the terminal segment of the right ureter The left side was normal whereas excretion and drainage on the right side were markedly delayed This delay was most marked at the second examination which was prolonged until one hour after the injection of contrast medium By that time the nephrographic effect still persisted on the right side and no contrast medium had become visible in the right renal pelvis or ureter

The patient was referred for repeat examination 5 days later He was then without pain but the stone persisted at the same site Films exposed before injection of contrast medium revealed that the nephrographic effect of the previous examination had subsided and that

Fig 2 Case 3 Peritoneal fibrosis a b) Right sided retrograde pyelography 9 days before nephrectomy Hydronephrosis and segmental narrowing of ureter Conventional films c) supine horizontal d) supine 45 head-down 7½ months after nephrectomy Contrast medium retained in right ureter differing with posture

contrast medium had instead become retained in the slightly dilated right renal pelvis and ureter

Case 3 A woman aged 49 years sought advice for non-characteristic abdominal pain Twenty five years previously she had undergone bilateral salpingo-oophorectomy because of salpingitis but the microscopy of the specimens obtained had suggested malignant ovarian cystadenoma and she had therefore received postoperative radiation therapy

Urography revealed bilateral hydronephrosis but failed to demonstrate the ureters Left sided retrograde pyelography revealed marked narrowing of the ureter Surgical exploration confirmed these findings and revealed firm fixation of both ureters by abnormal fibrous tissue which was most extensive on the right side Bilateral ureterolysis was carried out, and both ureters were left in an intraperitoneal position At urography 7 months later the dilatation of the renal pelvis had decreased considerably on the right side and disappeared on the left and the excretion as well as the further passage of contrast medium had become normal on both sides

At urography the following year no abnormality on the left side was found but on the right side no excretion of contrast medium was seen despite prolongation of the examination Right sided retrograde pyelography with Isopaque 350 revealed a recurrence of hydronephrosis and marked narrowing of a short presacral segment of the ureter which was slightly dilated above and below that segment (Fig 2 a b) Right sided nephrectomy 9 days

Fig 3 Case 4 Carcinoma of prostate a) Vasoseminal vesiculography Narrow segment of left ejaculatory duct b) Conventional film 2 months later Contrast medium retained in seminal vesicles

later disclosed that the entire right ureter had again become enveloped in firmly adherent fibrous tissue It could therefore not be safely dissected and was left in situ

Conventional films of the abdomen were again obtained 7½ months after the nephrectomy The right ureter still contained highly concentrated contrast medium which proved to be intraluminal since it demonstrated the ureter above the narrow segment to an extent that differed with the posture of the patient (Fig 2 c d) A minor amount was also seen below the narrow segment the extension of which could therefore still be evaluated in the films

The further clinical course prohibited radiologic follow up A malignant neoplasm was revealed in the vaginal fornices and biopsy suggested metastasis of the ovarian tumor removed more than 25 years previously In an endeavour to remove all the malignant tissue hysterectomy was performed despite the extensive fibrosis which required simultaneous resection of the urinary bladder and removal of the right ureter together with adherent fibrous tissue No attempt was made to dissect the ureter or to analyse its contents but on microscopy of the removed tissues the ureter was identified and was not found to have any intraluminal or mural calcification

Case 4 A man aged 73 years with suggested carcinoma of the prostate which was large and firm on palpation Needle biopsy and serum phosphatase were normal Prostatectomy was contemplated and as a preliminary measure bilateral vasectomy was carried out On both sides a cannula was introduced into the vas deferens for vasoseminal vesiculography with Urografin 60% The contrast medium entered the seminal vesicles and ejaculatory ducts from which it passed via the urethra into the bladder The procedure revealed a short narrow segment of the left ejaculatory duct strongly suggestive of prostatic carcinoma (Fig. 3 a) A new biopsy specimen was therefore obtained by transurethral resection of the prostate Microscopy of the specimen confirmed the diagnosis and hormone therapy was instituted

Routine radiologic bone survey 2 months after the vesiculography revealed persistence of the contrast medium in both seminal vesicles (Fig 3 b) 5 months later the contrast medium was no longer visible

Discussion

TUFFIER (1894) seems to have been the first to afford evidence that the walls of the urinary tract may prevent certain water soluble substances in the luminal contents from escaping to the circulation He injected 2 cg of strychnine into the renal pelvis of a dog and found no poisonous effect of this dose unless the ureter had been ligated before the injection was made Using an isotope technique PERSKY et coll (1955) also in experiments with dogs demonstrated that following ligation of the ureter even large size molecules and colloidal gold disappeared from the renal pelvis suggesting that this escape was due to pyelovenous reflux

MARSHALL and his co workers performed a series of experiments with dogs in which an isolated ureter was perfused with a solution containing radioactive sodium diatrizoate and found that an average of 1 1 per cent of the contrast medium was absorbed in 2 hours During the first half hour the average resorption was only 0 1 per cent In another series pyelography with Hypaque containing the same substance was performed following ligation of the ureter Under these conditions the average resorption in a 2 hour period was found to be 6 9 per cent if the intraluminal pressure was low and 17 8 per cent if it was high In the latter case films were obtained to exclude obvious rupture of the collecting system (CASTELLINO & MARSHALL 1970 MARSHALL & CASTELLINO 1970)

In patients with occluded or surgically disconnected ureters MALUF (1953 1955) found that although water disappeared much slower from the bladder than from the rectum under similar conditions the introduction of Urokon 70 % into the bladder resulted in excellent pyelograms 4 hours later Other water soluble substances disappeared from the bladder at rates consistent with simple diffusion

The results obtained in the experiments mentioned suggest that water soluble substances may escape transmurally less easily from the ureter than from the renal pelvis or the urinary bladder and thus raise the question whether these parts of the urinary system provide mural barriers with different properties It is therefore interesting that the present observations in man revealed much longer retention of water soluble contrast medium in a stenotic ureter after nephrectomy than in the obstructed urinary tract in patients with ureteral stone The conditions in urolithiasis are however generally less informative because in such cases it cannot be excluded that the contrast medium is eliminated partly or entirely by reflux

No previous observation suggesting a similar barrier in the genital tract seems to be on record The prolonged retention of water soluble contrast medium in the seminal vesicles documented in one of the present cases has however not been unique in this department In several patients subjected to vasoseminal vesiculography after vasectomy subsequent radiologic search for metastases from a prostatic carcinoma revealed that contrast medium persisted in the seminal vesicles for weeks or months

Since the present observations were made in patients under far from normal condi

a b

Fig. 3. Case 4. Carcinoma of prostate. a) Vasoseminal vesiculography. Narrow segment of left ejaculatory duct. b) Conventional film 2 months later. Contrast medium retained in seminal vesicles.

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HYDRO AND HEMODYNAMIC EFFECTS OF CATHETERIZATION OF VESSELS

V Experimental and clinical catheterization of stenoses

L. BJORNO and H PETTERSSON

The introduction of a catheter into a vessel may disturb the hemodynamic state that existed before the catheterization (BJORNO & PETTERSSON 1976 b HELLSTEN & PETTERSSON 1977) The catheterization through local constrictions for instance across atherosclerotic plaques will further disturb the hemodynamic state This may have a severe influence upon the volumetric flow rate through the vessel and the pressure measured proximal and distal to the stenosis

An experimental estimation of the hydrodynamic influence of catheterization of stenoses is presented in the present report Special attention has been given to the variation of the static pressure in and the volumetric flow rate through the catheterized stenosis

The measurements were performed by means of the mechanical model described in detail in Part I (BJORNO & PETTERSSON 1976 a)

Theoretical considerations

Steady and unsteady flow of Newtonian liquids through stenoses has been the subject of a number of recent reports (BJORNO & PETTERSSON 1976 b FORRESTER & YOUNG 1970 HUGH & O MALLEY 1975 KOZMAN & FORRESTER 1972 LEE & FUNG

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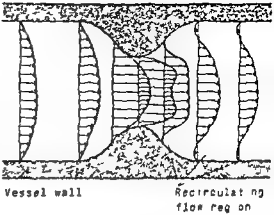

Fig. 1. Velocity profile variation through a stenosis that reduces the lumen area of the vessel 75 per cent. It is valid only for steady flow at low Reynolds numbers. Recirculating flow region (the area of separation) distal to the narrowest part of the stenosis. The exact positions of the separation point and the reattachment point of the recirculating region are not outlined.

1970; YOUNG & TSAI 1973). Both theoretical and experimental approaches have been used in order to analyse the complicated flow through a stenosis.

The nonlinear nature of the differential equations governing the flow through the stenoses limits the possibility of obtaining a theoretical solution to the flow problem. An approximate solution was published by FORRESTER & YOUNG (1970), accounting for some of the features of the flow through a stenosis, as for instance the variation in the velocity profile, the pressure and the wall shearing stress through the stenosis, together with the critical Reynolds number required for flow separation to occur. Their analysis was based upon the assumption of mild stenoses and of a parabolic velocity profile of the vessel flow. In a subsequent report LEE & FUNG (1970) gave a numerical solution to the Navier-Stokes equations describing the flow through a stenosis. In both works the constriction is considered axially symmetric and the solutions are valid for rather low Reynolds numbers (LEE & FUNG: $Re < 25$). These works both reflect the mathematical and numerical difficulties associated with a theoretical solution and description of the flow through a stenosis.

A schematic outline of the flow through a stenosis in which the lumen area of the vessel is reduced by 75 per cent is illustrated in Fig. 1. It is valid for steady flow at low Reynolds numbers. The shape of the velocity profile markedly changes during the flow through the stenosis. Distal to the narrowest part of the stenosis a recirculating flow region occurs (area of separation), limited by a separation point and a reattachment point. The size of this recirculation flow region, as well as the medical consequences of the establishment of a recirculating flow region have been subjected to a number of experiments reported by FORRESTER & YOUNG (1970), HUGH & O'MALLEY (1975), KOZMAN & FORRESTER (1972) and YOUNG & TSAI (1973).

In general 3 basic regimes of flow of medical significance are encountered in the flow through a stenosis:

(1) For very low Reynolds numbers no separation flow is observed and the flow through the stenosis is laminar and unidirectional throughout the constriction.

(2) For higher Reynolds numbers the flow remains laminar but a laminar separa-

tion takes place on the distal side of the stenosis leading to the formation of a re circulating flow region With increasing Reynolds number the laminar separation point moves upstream towards the narrowest part of the stenosis while the reattach ment point moves downstream thus increasing the recirculating flow region

(3) The third regime of flow is one in which the flow downstream from the separa tion point is highly turbulent This flow regime occurs for high Reynolds numbers and no local region of recirculating flow is discernible within it

Geometrical thermodynamical and physical factors influence the transition of the flow from one regime to another and no fixed Reynolds number can be given for the transition

The very low Reynolds numbers necessary to avoid separation (back flow) in a divergent tube due to increasing static pressure has been shown by BLASIUS (1910) to be determined by the expression

$$\frac{dR}{dx} < \frac{12}{Re} \quad (1)$$

where R is the radius of the tube x is the axial coordinate and Re $(=U2R/\nu)$ denotes the Reynolds number (U and ν are the volumetric mean velocity and the kinematic liquid viscosity respectively) Reynolds numbers exceeding the limit given by eq (1) occur in a great number of vessels in the human body This fact has stimulated interest in the investigation of flow through stenoses and in its medical consequences These consequences may for instance be the adhesion of platelets and probably thrombus formation in the large area of relative stagnant flow in the recirculating flow region (FOX & HUGH 1966 FORRESTER & YOUNG 1970) Moreover as the Rey nolds number increases the flow will become turbulent which may cause post stenotic dilatation (RODBARD 1967) The relatively large velocity gradients occurring in the converging section of a severe stenosis together with the pressure and velocity fluctuations due to turbulence may affect the endothelial lining causing deterioration of the endothelial cells (FRY 1968 TEXON et coll 1965)

The severity of the stenosis strongly influences the pressure drop across the ste nosis The increased pressure drop is among other things due to early transition from laminar to turbulent flow a transition which in constricted tubes will occur at relatively low Reynolds numbers well below the critical values for flow in straight tubes Where turbulent flow is found only experimental methods are able to yield reliable information about the flow parameters that form the basis for evaluations of the medical consequences of the flow through stenoses This should be one of the most important reasons why theoretical investigations of flow through constrictions are so sparely represented in the literature

If a catheter is introduced through a stenosis the complications attributed to a mathematical description of the stenosis flow even at very low Reynolds numbers will be seriously increased As shown by BERÁNEK (1969 1971) and BERÁNEK et coll (1970) the introduction of a catheter through a stenosis may strongly increase the

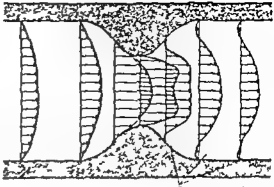

Fig. 1 Velocity profile variation through a stenosis that reduces the lumen area of the vessel 75 per cent It is valid only for steady flow at low Reynolds numbers Recirculating flow region (the area of separation) distal to the narrowest part of the stenosis The exact positions of the separation point and the reattachment point of the recirculating region are not outlined

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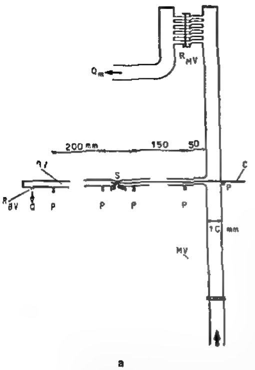

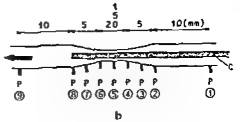

Fig 2 a) Experimental set up showing the main vessel (MV) and the branch vessel (BV) in which a stenosis (S) has been inserted A catheter (C) has been fed through a hole in the main vessel and introduced through the stenosis The position of the catheter is coaxial in the branch vessel and in the stenosis b) The geometry of the stenosis with oblique in let and outlet together with the introduced catheter

→ denotes the direction of the fluid flow R_{MV} Interchangeable peripheral resistance of the main vessel R_{BV} Interchangeable peripheral resistance of the branch vessel Q Site for measurement of the volumetric flow rate through the branch vessel Q_m Site for measurement of the volumetric flow rate through the main vessel P Needles for static pressure measurements The needles are flushmounted with the inner vessel wall and connected via polyethylene catheters to pressure transducers ①-⑨ denote the position for static pressure measurements (P) across the stenosis as well as the different positions of the catheter tip at which measurements have been performed during the catheterization procedure (the catheter tip in this figure situated in position ①

liquid outlet takes place into free air and not into a vessel The present experimental results seem to support this statement

On the basis of these rather brief theoretical considerations it may be concluded that a numerical solution to the Navier Stokes equations for the boundary conditions given by the stenosis surface and the catheter probably may be obtained for very low Reynolds numbers and for mild stenoses However the mathematical and numerical difficulties associated with such a procedure will be extensive and probably out of proportion to the medical benefits gained

A clinically more important subject for investigation is the flow at higher Reynolds numbers through catheterized severe stenoses For the present this must be analysed through experiments in acknowledgement of the fact that the answer from nature will come closest to the truth

pressure loss across and decrease the flow through the stenosis. This may lead to serious errors and false conclusions from catheter measurements of pressures and volumetric flow rates, if the influence of the catheter on the flow through the stenosis is not taken into consideration.

GORLIN & GORLIN (1951) derived an expression for the calculation of the area of a stenotic mitral valve, as well as other cardiac valves, by comparing the flow through it with the flow through a rounded edge orifice, which is one of the early problems of hydraulics. This old problem originally concerned the hydrodynamics of a liquid outlet through a rounded-edge orifice into free air. The expression derived by GORLIN & GORLIN is

$$A = \frac{F}{C \cdot 44.5\sqrt{p_1 - p_2}} \tag{2}$$

where A is the cross sectional area of the orifice (constriction lumen area), F is the volumetric flow rate through the orifice and p_1 and p_2 are the pressure heads proximal and distal to the orifice.

The dimensional constant C is, among other things, a function of the coefficient of orifice contraction and the coefficient of conversion of pressure into velocity. This means that the character of the flow as laminar or turbulent or both, the geometry of the orifice, the roughness of the orifice surface, etc. will influence the value of C. Thus C can be determined only by experiments.

Equation (2) has been used by BERÁNEK (1971) for calculation of the reduced flow and the increased pressure loss through a catheterized stenosis compared with a free stenosis. By putting $C = C_k$, where C and C_k denote the C values for the free and for the catheterized stenosis, respectively, BERÁNEK derived an expression for the increased pressure loss due to the presence of the catheter.

By putting $C = 1.03\ C_k$ he derived an expression for the reduced volumetric flow rate through the catheterized stenosis. In spite of a reasonable agreement claimed between his experimental results and the calculations based on his derived theoretical expressions, his use of the eq. (2) must be assumed to lead to an oversimplification of the character and the consequences of the flow through a catheterized stenosis. As shown by BJORNO & PETTERSSON (1976 b, 1977), the introduction of a catheter into a vessel may lead to the transition from laminar to turbulent flow. This transition is strongly dependent on the annular lumen area between the vessel (or stenosis) and the catheter. Moreover, the degree of eccentricity in the position of the catheter will influence the static pressure loss in and the volumetric flow through the catheterized stenosis. It is also obvious that the introduction of a rod into an orifice flow will change both the coefficient of orifice contraction and the coefficient of pressure to velocity conversion. All these facts should lead to the conclusion that eq. (2) reasonably may be used for a comparison only between pressure losses at various volumetric flow rates of the same liquid through the same orifice when the

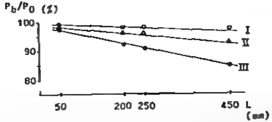

Fig 3 Dimensionless static pressure (p_b/p) measured along the unstenosed and uncatheterized branch vessel compared with the calculated variations in static pressure in Poiseuille flow for the same volumetric flow rates p_b static pressure measured at various sites along the branch vessel p_0, static pressure in the main vessel constant = 12 10^3 Pa L, the distance from the main vessel along the branch vessel ○ △ ● denote measured pressure — denotes calculated value I the pressure variations for Q_0 = 97 ml/min. II the pressure variations for Q = 172 ml/min III the pressure variations for Q = 410 ml/min

and

$$D_c = \frac{A}{A_s} \; 100(\%) \tag{4}$$

where D denotes the percental lumen area reduction of the vessel produced by the stenosis and D_c the percental lumen area reduction of the stenosis produced by the introduced catheter A_v and A denote the lumen area of the branch vessel and of the stenosis respectively A is the cross sectional area of the introduced catheter

The volumetric flow rate in the branch vessel was measured by a modified flow meter (Siemens Elema EMT 434 see BJORNO & PETTERSSON 1976 a) Hypodermic needles flushmounted with the inner vessel wall were used for static pressure measurements (Fig 2 b) The needles were connected via polyethylene catheters to pressure transducers (Siemens Elema EMT 34 0 to 300 mmHg) The measurements were recorded on paper tape (Mingograf 800) and the accuracy in the measurements of volumetric flow rate and of the pressure was ± 2 per cent of full scale display

The static pressure in the main vessel opposite the inlet to the branch vessel (P_0) was kept constant at 12 10^3 Pa

The volumetric flow rate through the main vessel was 2 000 to 2 200 ml/min Three different peripheral resistances of the branch vessel were used in the experiments giving a volumetric flow rate through the branch vessel without stenosis or catheter (Q_0) of 97 ml/min 172 ml/min and 410 ml/min respectively

The fluid used was a mixture of glycerol and water at a temperature of 30 C having a dynamic viscosity of 3 8 cP and a density of 1 100 kg/m³ The flow throughout the experiments was steady

Results and Discussion

Insertion into eq (1) of the Reynolds numbers actual for the experiments performed (Table 2) together with the geometry of the outlet section of the stenosis

Table 1

Lumen area reductions according to eqs (3) and (4). The lumen area reduction of the branch vessel caused by the catheter was 6 per cent. D_s percental lumen area reduction of the branch vessel in the stenosed part of the vessel. D_c percental lumen area reduction of the stenosis caused by the catheter

Diameter (mm)			Corresponding lumen area reduction (%)	
Vessel	Stenosis	Catheter	D_s	D_c
4.1	1.5	1.0	87	44
4.1	2.0	1.0	76	25
4.1	2.5	1.0	63	13

Table 2

The Reynolds numbers (Re) in the branch vessel for the volumetric flow rates (Q_b) through the free stenoses with throat diameters 1.5 mm and 2.5 mm

	Stenosis diameter 1.5 mm			Stenosis diameter 2.5 mm		
Q_b (ml/min)	94	162	320	97	172	405
Re	141	243	480	145	258	608

Material and Methods

The mechanical model used in the experiments consists of 3 main parts: (1) An apparatus producing controllable flow and pressure variations, (2) a model of the vessels with inserted stenosis to be catheterized, and (3) a recording device for pressure and volumetric flow rate measurements.

A detailed description of the vessel model is given in Part I (Bjorno & Pettersson 1976 a). In Fig. 2 the experimental set up is illustrated showing the dimensions of the model, the position of the stenosis, the sites for measurements of the static pressure and the model of catheterization. The catheterization was always performed downstream in the branch vessel. The vessels were made of perspex and thus rigid. The inner diameter of the branch vessel and the outer diameter of the catheter were 4.1 and 1.0 mm, respectively, throughout the experiments. The diameters of the narrowest part of the stenoses were 1.5 mm, 2.0 mm and 2.5 mm, respectively, and its lengths were 1.0 mm, 5.0 mm and 20.0 mm. The stenoses were axisymmetric. In all except one series of experiments the inlet and outlet surfaces of the stenoses were oblique (Fig. 2 b), the axial length of the inlet and outlet parts being 5 mm. One series of experiments was performed with right angled inlet and outlet of the stenosis.

Table 1 shows the lumen area reductions investigated, calculated from the equations

$$D_s = \frac{A_w - A_s}{A_w} \cdot 100 \, (\%) \qquad (3)$$

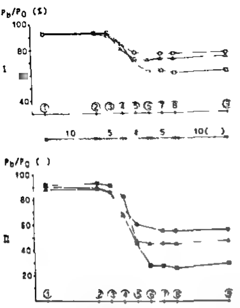

Fig 5

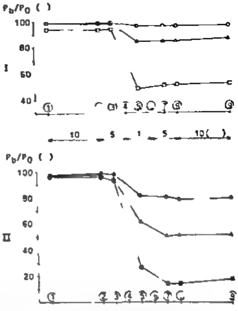

Fig 6

Fig 5 Dimensionless static pressure (p_b/p_0) measured at various positions ①–⑩ along the stenoses of various throat lengths I for the same original volumetric flow rate Q (Q = 410 ml min) Diameter of stenosis 2 0 mm I Free stenoses ○ stenosis length l = 1 mm (Q_b = 385 ml/min) – stenosis length l = 5 mm (Q_b = 385 ml/min) □ stenosis length l = 20 mm (Q_b = 350 ml/min) II Catheterized stenoses with the catheter tip at position ● stenosis length l = 1 mm (Q_b = 335 ml/min) ▲ stenosis length l = 5 mm (Q_b = 3_0 ml/min) ■ stenosis length l = 20 mm (Q_b = 250 ml min)

Fig 6 Dimensionless static pressure (p_b/p_0) measured at various positions –– along the stenosis for various volumetric flow rates Q Diameter of the stenosis 1 5 mm length of the throat of the stenosis 1 0 mm I Free stenosis ○ Q = 97 ml/min (Q_b = 94 ml/min) – Q = 172 ml/min (Q_b = 167 ml/min) □ Q_0 = 410 ml min (Q_b = 320 ml/min) II Catheterized stenosis with the catheter tip at position ① ● Q = 97 ml/min (Q_b = 80 ml/min) ▲ Q = 172 ml/min (Q_b = 125 ml/min) ■ Q = 410 ml/min (Q_b = 175 ml/min)

friction loss along the longer stenosis which again leads to a reduced volumetric flow rate through the stenosis for increasing length of the narrowest part

Influence of the diameter of the stenosis It is well known that it is necessary to have a marked stenosis of a vessel before the distal pressure and the volumetric flow rate are perceptibly reduced (BJORNO & PETTERSSON 1976 b) When this critical stenosis diameter is reached further small increases in the degree of the stenosis cause significant reduction in pressure and volumetric flow rate (MAY et coll 1963)

From Fig 6 it is evident that at volumetric flow rate Q_0 = 410 ml/min the stenosis with diameter 1 5 mm gives a marked reduction in pressure across and volumetric flow rate through the stenosis Thus for this Q_0 the stenosis has passed the critical value For the volumetric flow rate Q_0 = 172 ml/min the same stenosis is possibly just in the region of the critical value (Fig 6) The stenosis with diameter 2 5 mm

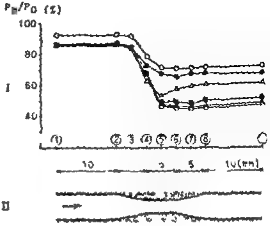

Fig. 4. I. Dimensionless static pressure (p_b/p_0) measured at various positions along the stenosis as a function of the penetration depth of the catheter into the stenosis. p_0 constant = 12·10³ Pa, Q_0 = 410 ml/min. II. The geometry of the stenosis corresponding to I. Diameter of the stenosis = 2.0 mm. 1–8 denote the positions for pressure measurements as well as for the different positions of the catheter tip. → denotes the direction of fluid flow. ○ free stenosis (Q_b = 385 ml/min); ● catheter tip at position 3 (Q_b = 375 ml/min); △ catheter tip at position (Q_b = 350 ml/min); ■ catheter tip at position 5 (Q_b = 330 ml/min); ▲ catheter tip at position (Q_b = 320 ml/min); catheter tip at position (Q_b = 320 ml/min).

shows that the limit for separation and formation of recirculating flow distal to the stenosis has been reached and exceeded by all experiments performed.

The pressure variation of the flow in the branch vessel, measured before insertion of the stenosis and without catheterization, appears in Fig. 3. The measured values are in good agreement with the pressure variation calculated on the basis of the expression for Poisseuille flow.

Influence of the penetration depth of the catheter into the stenosis. It is to be expected that during catheterization of a stenosis the penetration depth of the catheter into the stenosis will influence the pressure drop across the stenosis and the volumetric flow rate through the stenosis. This influence is illustrated by Fig. 4, which shows that the catheter penetration through the first half of the stenosis leads to the strongest influence upon the pressure course p_b and the volumetric flow rate Q_b through the stenosis. The same penetration depth influence was observed at lower Q_0 values, but it was not as prominent as for Q_0 = 410 ml/min.

Influence of the length of the stenosis. The length of the stenosis will also have an influence upon the pressure course p_b and the volumetric flow rate Q_b through the stenosis. Fig. 5 gives p_b and Q_b for the same geometrical shape of the inlet and outlet of the stenosis but for various lengths of the throat of the stenosis.

The fully catheterized stenosis (i.e. with the catheter tip at position 8) results in a strongly increasing pressure drop across the stenosis with increasing length of the narrowest part of the stenosis. This feature was also found at lower volumetric flow rates (lower Q_0), not shown in Fig. 5.

For a free stenosis and for a fully catheterized stenosis the static pressure will increase proximal to the stenosis for increasing throat length l. This is due to the greater

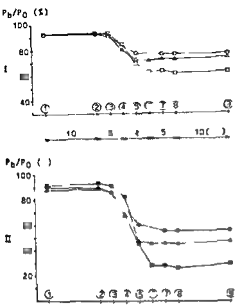

Fig 5

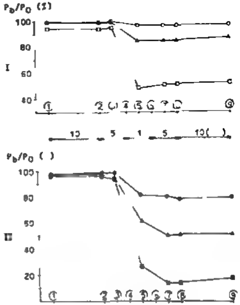

Fig 6

Fig 5 Dimensionless static pressure (p_b/p) measured at various positions ①–⑨ along the stenoses of various throat lengths l for the same original volumetric flow rate Q (Q =410 ml/min) Diameter of stenosis 2 0 mm I Free stenoses ○ stenosis length l=1 mm (Q_b=385 ml/min) – stenosis length l=5 mm (Q_b=385 ml/min) □ stenosis length l=20 mm (Q_b=350 ml/min) II Catheterized stenoses with the catheter tip at position ○ ● stenosis length l=1 mm (Q_b=335 ml/min) ▲ stenosis length l=5 mm (Q_b=320 ml/min) ■ stenosis length l=20 mm (Q_b=250 ml/min)

Fig. 6 Dimensionless static pressure (p_b/p) measured at various positions ①–⑨ along the stenosis for various volumetric flow rates Q_o Diameter of the stenosis 1 5 mm length of the throat of the stenosis 1 0 mm I Free stenosis ○ Q =97 ml/min (Q_b=94 ml min) – Q =172 ml/min (Q_b=162 ml min) □ Q =410 ml/min (Q_b=320 ml/min) II Catheterized stenosis with the catheter tip at position ○ ● Q =97 ml/min (Q_b=80 ml min) ▲ Q_o=172 ml/min (Q_b=125 ml/min) ■ Q =410 ml/min (Q_b=175 ml/min)

friction loss along the longer stenosis which again leads to a reduced volumetric flow rate through the stenosis for increasing length of the narrowest part

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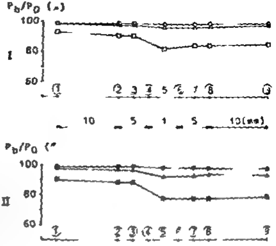

Fig. 7 Dimensionless static pressure (p_b/p_0) measured at various positions along the stenosis for various volumetric flow rates Q_0. Diameter of the stenosis 2.5 mm, length of the throat of the stenosis 10 mm. I Free stenosis ○ Q_0 = 97 ml/min (Q_b = 97 ml/min), Q_0 = 172 ml/min (Q_b = 172 ml/min), Q_0 = 410 ml/min (Q_b = 405 ml/min). II Catheterized stenosis with the catheter tip at position, ● Q_0 = 97 ml/min (Q_b = 97 ml/min), ▲ Q_0 = 172 ml/min (Q_b = 168 ml/min), ■ Q_0 = 410 ml/min (Q_b = 380 ml/min)

has not reached the critical value for any of the volumetric flow rates Q_0 = 410 ml/min, Q_0 = 172 ml/min or Q_0 = 97 ml/min (Fig. 7)

Catheterization of a critical stenosis (Q_0 = 172 ml/min) or a stenosis that has passed the critical value (Q_0 = 410 ml/min) will lead to a great reduction of the pressure across and the volumetric flow rate through the stenosis (Fig. 6). On the other hand if it is possible to avoid critical flow conditions in the stenosis, the catheter induced pressure drop will be quite small (Fig. 7). This is particularly the case for the flow through the free and the fully catheterized stenosis (diameter 2.5 mm) for volumetric flow rates Q_0 = 97 ml/min and Q_0 = 172 ml/min, while the loss, probably turbulent loss, for Q_0 = 410 ml/min leads to an increased pressure drop across the catheterized stenosis compared with the free stenosis

Attempts have failed to obtain a more clear-cut regularity of the limits for critical flow through catheterized stenoses based on the critical values for stenoses and the critical annular lumen area reduction discussed by BJORNO & PETTERSSON (1977)

Influence of the geometrical shape of the stenosis The geometrical shape of the stenosis will in particular at high volumetric flow rates have an influence upon the pressure course through the stenosis (BJORNO & PETTERSSON 1976 b)

A comparison between the stenosis with oblique inlet and outlet surfaces and that with right angled inlet and outlet appear in Fig. 8. In the stenosis with right angled inlet and outlet, the strongest pressure drop occurred between positions 4 and 5. This seems to be the case for both the free and the fully catheterized stenosis and is due to the conversion of pressure to velocity between these positions

The turbulence loss seems to be about the same for the two stenosis geometries with a slightly greater loss by the right angled stenosis

The use of formulas for calculation of the flow BERÁNEK (1971) has used Gorlin's formula (eq. 2) for a calculation of the pressure drop across and the volumetric flow

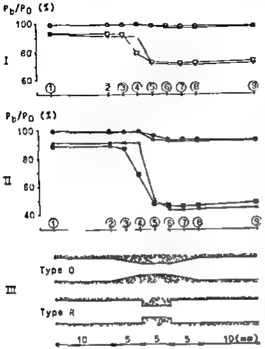

Fig 8 Comparison between dimensionless static pressure (p_b/p_0) measured at various positions ①–⑨ along a stenosis with oblique inlet and outlet (type 0) and a stenosis with right angled inlet and outlet (type R) for two different volumetric flow rates Q_0 (97 ml/min and 410 ml/min respectively) *Lumen diameter of the stenosis 2 0 mm* and length of the throat of the stenosis 5 0 mm for both types of stenoses I Free stenosis ○ Stenosis type 0 $Q_0 = 97$ ml/min $Q_b = 95$ ml/min △ Stenosis type R Q = 97 ml/min $Q_b = 95$ ml/min □ Stenosis type 0 Q = 410 ml/min $Q_b = 385$ ml/min + Stenosis type R Q = 410 ml/min $Q_b = 380$ ml/min II Catheterized stenosis with the catheter tip at position ⑩ ● Stenosis type 0 Q = 97 ml/min $Q_b = 92$ ml/min ▲ Stenosis type R Q = 97 ml/min $Q_b = 90$ ml/min ■ Stenosis type 0 $Q_0 = 410$ ml/min $Q_b = 320$ ml/min Stenosis type R Q = 410 ml/min $Q_b = 315$ ml/min III The geometry of the two types of stenosis

rate through a fully catheterized stenosis by putting $C = C_k$ for the pressure drop and $C = 1\,03\ C_k$ for the volumetric flow rate

For the same stenosis geometry a calculation of the C and C_k values was perform d for all individual experiments in all the test series A determination of the average of the C and C_k values found gave $C_{(m)} = 0\,85 \pm 0\,18$ and $C_{k(m)} = 0\,63 \pm 0\,15$ showing a strong mutual variation between the individual C and C_k values with the most essential contributions to the variation arising from the highest Q_0 values No basis was found for putting $C = C_k$ or $C = 1\,03\ C_k$ which if done will lead to an over simplification of the flow through the free and the catheterized stenosis Th conclusions concerning the use of Gorlin s formula for the calculation of the flow through free and catheterized stenoses are that the C and C_k values depend in a rather complicated way on the Reynolds number of the flow the geometry of the stenosis the ratio of the diameter of the stenosis and of the catheter etc This dependence should be determined for each individual flow condition b fore the us of eq (2)

Based upon the present experimental results it is evident that *an uncritical use of* Gorlin s formula for free or catheterized stenotic flow will lead to a strong deviation between predicted and measured values of the pressure drop and the volumetric flow rate which again may lead to erroneous conclusions

All attempts hitherto performed to develop simple relations b tween parameters describing the very complicated flow at high Reynolds numbers through free or

Table 3

Results of pressure measurements performed by a catheter introduced through a stenosis in the renal artery in 3 patients with hypertension

Case no	Diameter of stenosis (mm)	Diameter of catheter tip (mm)	Clinical significance of the stenosis	Arterial blood pressure (kPa)					
				Aorta			Renal artery distal to stenosis		
				Syst	Diast	Mean	Syst	Diast	Mean
1	3 1	1 4	–	26 7	12 0	17 1	26 4	11 7	16 8
2	2 2	1 4		24 8	14 3	16 0	14 3	10 7	11 3
3	1 8	1 4		22 7	11 7	14 7	3 3	2 8	3 0

catheterized severe stenoses have been without success Experiments are still the only source of more exact information for each individual flow case

Clinical considerations

In the experiments reported the fluid used was Newtonian the flow steady the vessel walls were rigid the geometry of the stenoses was symmetric and the stenoses as well as the catheter coaxially placed in the vessel Thus the experimental situation differs from the conditions in living animals or humans However with the flow conditions analysed blood may be regarded as Newtonian (BJORNO & PETTERSSON 1976 b FORRESTER & YOUNG 1970) Despite the other differences between the model and the clinical situation the experiments should give some insight into and ideas of the hemodynamic consequences of clinical catheterization through arterial stenoses

To give a crude impression of the clinical applicability of the results 3 examples of pressure registration through a catheter in different degrees of renal artery stenosis are presented

Lumbar aortography for examinations of the renal arteries using the method described by BOIJSEN & JUDKINS (1966) was performed in 3 patients with hypertension After the semiselective examination the catheter was replaced by another without sideholes The distal 4 cm of this catheter had an outer diameter of 1 4 mm inner diameter of 0 9 mm The rest of the catheter had an outer diameter of 2 2 mm inner diameter of 1 45 mm Its length was 80 cm The tip of the catheter was introduced through the stenosis and the catheter was connected to a pressure transducer (Siemens Elema EMT 34 0 to 300 mmHg) While withdrawing the tip of the catheter to the aorta the pressure events were continuously measured and recorded on paper tape (Mingograf 800) After that the renal artery was again catheterized and selective

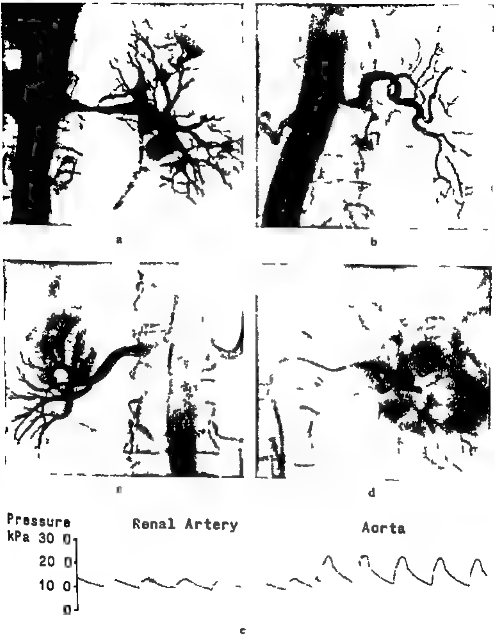

Fig. 9 Clinical examples a b c Semiselective angiographies revealing the renal artery stenosis in patients Nos 1 to 3 a) Patient No 1 diameter of the stenosis 3 1 mm b) Patient No 2, diameter of the stenosis 2 2 mm. c) Patient No 3 diameter of the stenosis 1 8 mm d) Selective angiography in patient No 1 with the catheter used for pressure measurements The tip of the catheter is placed distal to the stenosis e) Pressure measurements recorded in patient No 2 during withdrawal of the catheter tip from a position in the renal artery distal to the stenosis to a position in the aorta A considerable pressure gradient is evident (see Table 3)

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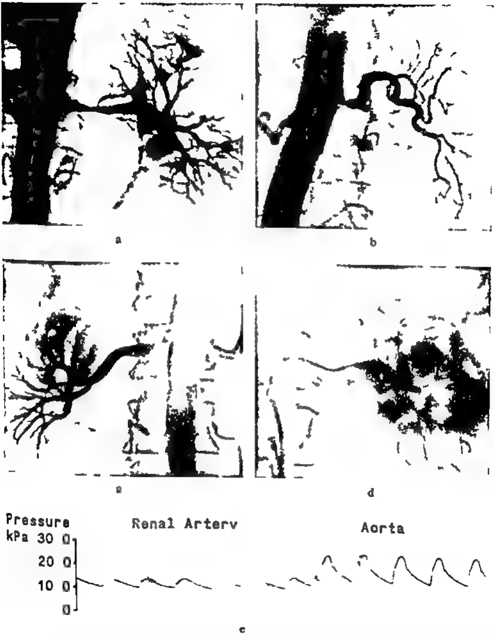

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nephroangiography was performed using a geometrical magnification method. The linear magnification factor was about 2.5. This made possible an exact determination of the stenosis diameter using the known catheter diameter as a reference.

The results for the three patients are given in Table 3. The diameter of the unstenosed part of the renal artery in the 3 patients and the stenosis induced percental lumen area reduction are not given in the table. The reason for this is that an exact determination of the diameter of the artery is difficult to perform: in patients Nos 2 and 3 the stenosis is located near to the aorta, and in patient No. 3 there is a post-stenotic dilatation (Fig. 9). However, the diameters of the renal artery on the unaffected side in the patients are equal, and there is reason to assume that the diameters of the stenoses reflect a corresponding degree of percental lumen area reduction in the three vessels.

The renal blood flow is not known. However, the circulation time through the kidney, estimated as the time between the beginning of the contrast medium injection and the filling of the most peripheral arterial branches, was the same in the 3 patients (1.5 s).

Only patient No. 3 had a clinically significant stenosis as estimated from the renal vein renin determinations and the result of operation (SIMMONS & MICHELAKIS 1967, JUNCOS et coll. 1974).

In patient No. 1 (diameter of the stenosis 3.1 mm) no pressure gradient was recorded over the stenosis (Table 3). A considerable attenuation of the pulse peak pressure and reduction of the pulse mean pressure was evident in patient No. 2 (diameter of the stenosis 2.2 mm (Fig. 9). In patient No. 3 (diameter of the stenosis 1.8 mm) the pulse peak pressure was nearly totally damped and the pulse mean pressure was heavily reduced.

The true pressure gradients (the pressure gradients across the stenoses without catheters) are not known. However, in patient No. 1 no pressure gradient was revealed at catheterization. In patient No. 2 it is doubtful whether any true pressure gradient existed across the stenosis, and probably most of the recorded pressure reduction was caused by the presence of the catheter. In patient No. 3, with a clinically significant stenosis, the recorded pressure reduction across the stenosis should be the result of a combination of the true pressure gradient and that caused by the catheter.

In accordance with the findings of BERÁNEK et coll. (1969) and CARTER & RITCHIE (1966) the recorded pressure reduction was greatest on the systolic pressure.

Conclusions

(1) While theoretical solutions exist that describe the flow through mild stenoses at low Reynolds numbers, no satisfactory theoretical solution describes the flow through a stenosis in which a catheter has been introduced.

(2) The mathematical problems associated with such a solution would be extensive and probably out of proportion to the medical benefit gained.

(3) The pressure course across and volumetric flow rate through a catheterized stenosis thus must be analysed in experiments

(4) In model experiments for steady flow and downstream catheterization the following conditions are valid

(a) The penetration of the catheter through the proximal half of the stenosis has the greatest effect on the pressure course and the volumetric flow rate through the stenosis

(b) The catheter induced reductions in pressure and volumetric flow rate increase with increasing length of the stenosis

(c) For a fixed catheter diameter the effect of the catheter increases with increasing volumetric flow rate through the stenosis before catheterization and the effect increases with decreasing diameter of the stenosis

When a stenosis with a diameter that is close to or below the value for the critical stenosis is catheterized the catheter has a marked effect on the reduction of pressure and volumetric flow rate across the stenosis

In stenoses of greater diameters where critical flow conditions are not achieved the catheter effect is of low order

(d) The pressure losses along a catheterized stenosis with right angled inlet and outlet is slightly larger than along a catheterized stenosis with oblique inlet and outlet for the same volumetric flow rate

(5) The model experiments in spite of differences from clinical situations should give valuable information on the hemodynamic effects of catheterization of stenoses in animals and humans

(6) When a catheter is introduced through a stenosis for pressure measurements and a pressure gradient is recorded across the stenosis the catheter itself has contributed to the pressure gradient In the individual case the magnitude of this contribution may be difficult to determine However the experience from such pressure measurements across for instance renal artery stenoses in a great number of patients may give additional information about the hemodynamic significance of a stenosis It should be of value when it is impossible to determine the diameter of the stenosis radiologically

Acknowledgement

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SUMMARY

The volumetric flow rate and the pressure course through free and catheterized stenoses have been analysed experimentally The influence of the following parameters has been considered (a) the penetration depth of the catheter into stenoses of various geometrical shapes and various dimensions (b) the length of the stenosis (c) the size of the annular lumen area between the catheter and the stenosis wall (d) the geometrical shape of the ste

nosis Some previous attempts to derive a simple relation between the volumetric flow through and the pressure fall across stenosis with and without introduced catheter are discussed Clinical pressure measurements across renal artery stenoses are given and the validity of catheter measured pressure gradients across stenoses is discussed

ZUSAMMENFASSUNG

Die volumetrische Durchstromungsgeschwindigkeit und der Druckverlauf durch freie und katheterisierte Stenosen wurde experimentell analysiert Es wurden der Einfluss der fol genden Parameter festgestellt (a) die Penetrationstiefe des Katheters in Stenosen verschie dener geometrischer Formen und unterschiedlicher Dimensionen (b) die Lange der Stenose (c) die Grosse der ringformigen Lumenflache zwischen dem Katheter und der Wand der Stenose (d) die geometrische Form der Stenose Es werden einige fruheren Versuche eine einfache Relation zwischen der volumetrischen Durchstromungsgeschwindigkeit und dem Druckabfall durch die Stenose mit und ohne eingefuhrtem Katheter herzuleiten diskutiert Die klinischen Druckmessungen durch Stenosen der A renalis werden gegeben und die Validitat der Kathetergemessenen Druckgradienten uber die Stenosen diskutiert

RESUME

Le taux de debit volumétrique et l évolution de la pression a travers des sténoses libres et des sténoses cathetérisées ont eté étudiés expérimentalement Les auteurs ont examiné l influence des paramètres suivants (a) la longueur de la pénétration du cathéter dans des stenoses de forme géométrique variée et de dimension variée (b) la longueur de la sténose (c) les dimensions de la lumière annulaire entre le catheter et la paroi de la sténose (d) la forme geométrique de la sténose Ils examinent certaines tentatives précédentes pour établir une relation simple entre le taux de débit volumetrique à travers la sténose et la chute de pression à travers la sténose avec ou sans introduction d un cathéter Les mesures cliniques de pression à travers les sténoses de l artère rénale sont indiquées et les auteurs étudient la validité des gradients de pression mesurés par cathetérisme à travers la sténose

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ANGIOGRAPHY IN RETICULUM CELL SARCOMA

U. ALBRECHTSSON and U. TYLÉN

The angiographic appearances of reticulum cell sarcoma in various organs are reported by the following authors: stomach (BOIJSEN et coll. 1966, EISEN & FISCHERMAN 1974), intestine (BOIJSEN & REUTER 1966, LUNDERQUIST et coll. 1971, DE SCHEPPER et coll. 1974), spleen (RÖSCH 1966, GOULD et coll. 1970, EKELUND et coll. 1975), pancreas (NEIMAN et coll. 1975, TYLÉN 1975), kidney (LALLI 1969), bone (STECKEL 1966, YAGHMAI et coll. 1971) and retroperitoneal space (LAMARQUE et coll. 1970, KAHN 1971, LOWMAN et coll. 1972, LEVIN et coll. 1973). In these reports only solitary cases are described, which motivated the present report on a relatively large series of reticulum cell sarcoma in various locations.

Material and Methods

The series comprised 14 patients (6 males and 8 females) aged 36 to 76 years. The diagnosis was confirmed by operation or postmortem examination in 12 patients and by fine needle biopsy in 2 patients. The series includes 2 cases previously reported by EKELUND et coll. and 3 cases reported by TYLÉN. One patient is included in the material of both these authors. Choice of aortography, celiac angiography, superior mesenteric angiography or nephroangiography was dependent upon the localization of the tumor. All films were analyzed in retrospect as to the usual criteria of tumor growth, i.e. presence of arterial or venous encasement, newly formed vessels and vascular displacement.

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Fig. 1 Female aged 74 with reticulum cell sarcoma of the retroperitoneal area involving the pancreas and spleen Irregular encasement of the splenic artery The small arteries to the tail of the pancreas and hilum of spleen irregular and tortuous

Results

Reticulum cell sarcoma growing into the retroperitoneal space and involving the spleen or the tail of the pancreas occurred in 5 patients all displaying the same angiographic appearances The spleen was enlarged in 3 of the patients the enlargement was marked and the intrasplenic arteries were displaced The splenic artery and its branches were encased in all 5 patients the encasement having an irregular outline in 3 (Fig 1) while being smooth in 2 In all tumors abundant tortuous irregular newly formed vessels existed Despite this the tumor did not appear markedly hypervascular due to the rich vascularity of the surrounding splenic tissue The splenic vein was occluded in 2 patients and compressed in the remaining 3

The kidneys were displaced laterally in 4 patients in one of these also the intrarenal arteries were displaced indicating intrarenal growth In 2 patients the retroperitoneal lesions were hypervascular with abundant newly formed vessels and the renal veins were compressed (Fig 2) In the other 2 patients the vascularity was sparse and the tumor diagnosis was based on displacement of the kidneys and vessels (in one case on splenic vein compre sion in addition)

Reticulum cell sarcoma of the gastrointestinal tract was present in 4 patients in the stomach in 3 and in the small bowel in one All cases had hypervascularity and some newly formed vessels Arteriovenous shunting was demonstrated in the tumor of the small bowel (Fig 3) One of the gastric tumors infiltrated the pancreas and the pancreatic arteries were encased No encasement of vessels or arteriovenous shunting was evident in the slightly hypervascular gastric part of the tumor The appearance was similar in the other 2 patients with gastric tumors

A single metastasis in the left lobe of the liver was demonstrated in one of the patients with the primary lesion located in the stomach The metastasis displaced arterial branches but was hypovascular Due to its size it also compressed the splenic

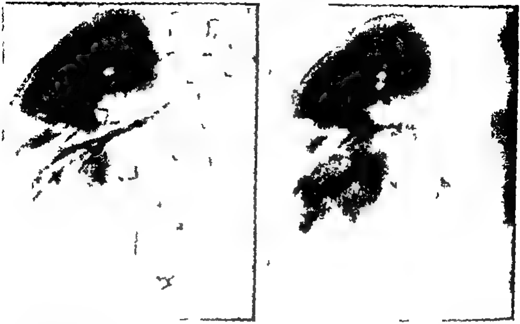

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Fig. 2 Male aged 69 with reticulum cell sarcoma of the retroperitoneal space invading the right kidney a) Tumor supplied mainly from capsular arteries Irregular and tortuous vessels in the area of lower pole and hilum of the kidney b) Obstruction of the vein from the lower pole of the kidney Filling of collateral veins

vein In another patient a reticulum cell sarcoma occurred in the liver but no extra hepatic lesion was found Also this tumor was hypovascular arterial displacement being the only finding

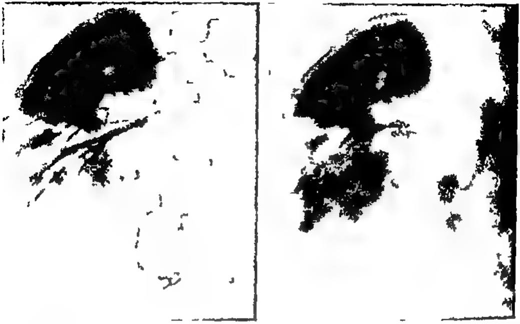
Discussion

Reticulum cell sarcoma is a tumor composed entirely of reticulum cells The most frequent location is in the retroperitoneal lymph nodes the spleen and the lymphoid tissue in the gastrointestinal tract The tumor may also arise in extralymphoid tissues the more common location being in bone and the central nervous system Microscopically the tumor is characterized by diffuse growth of reticulum cells with complete obliteration of the normal structure of the lymph node The tumor invades adjacent tissues in a manner similar to any malignant tumor Metastases are also common The prognosis is grave most patients die within 2 to 3 years (ROBBINS 1962)

The reticulum cell sarcoma thus demonstrates all characteristics of an invading malignant tumor It is therefore surprising that the most common description of the angiographic appearances is that of an avascular expansive lesion In the present series different angiographic appearances were found in different sites The lesions involving the tail of the pancreas and adjacent part of the retroperitoneal space displayed arterial encasement and venous occlusion as do pancreatic carcinomas

Fig. 3 Female aged 75 with reticulum cell sarcoma of the small bowel a) Tumor involvement of several loops of the ileum b) Irregular vasa recta in the area involved by the tumor (→) c) Early venous filling from the tumor (→)

However pancreatic carcinoma is generally of low vascularity tumor vessels being sparse (GOLDSTEIN et coll 1974 among others) MARIONS (1974) stated that pancreatic carcinoma has no newly formed vessels at all which is supported by the findings of UDÉN (1976) NEIMAN et coll reported the angiographic appearances of 4 cases of reticulum cell sarcoma Arterial encasement was evident in 3 but neovascularity in only one Disproportionate vascular displacement was characteristic in all cases A similar case was also reported by BRON et coll The present series indicates that reticulum cell sarcoma involving the pancreas is hypervascularized in distinction from pancreatic carcinoma Even if this finding is not diagnostic it suggests a type of tumor other than pancreatic carcinoma (TYLÉN) Reticulum cell sarcoma of the



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ZUSAMMENFASSUNG

Angiographie wurde bei 14 Patienten mit einem Retikelzellsarkom vorgenommen Bei Lokalisation in den retroperitonealen Geweben der Milz oder dem Pankreas ist der Tumor hypervaskular mit Infiltration der Arterien und Kompression oder Invasion der Venen Tumoren der Nieren zeigen ein ahnliches Bild Ein Magentumor zeigt leichte Veranderungen vorwiegend Hypervaskularitat und die Veränderungen lassen sich besser durch Barium untersuchung darstellen Ein Fall eines Retikelzellsarkoms des Dunndarms zeigte eine arterielle Infiltration und arteriovenose Shuntbildung

RESUME

Une angiographie a ete faite a 14 malades atteints de reticulosarcome Quand elle est située dans les tissus retroperitonéaux la rate ou le pancreas cette tumeur est hypervasculaire avec infiltration des parois des artères et compression ou envahissement des veines Les tumeurs des reins peuvent avoir un aspect semblable Une tumeur gastrique presente de legères anomalies surtout une hypervascularite la lesion etant mieux mise en évidence par l examen baryte Un cas de reticulosarcome dans l intestin grele a presente une infiltration arterielle et des shunts arterioveineux

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FROM THE DEPARTMENT OF RADIOLOGY MEDICAL COLLEGE OF VIRGINIA HOSPITALS
RICHMOND VIRGINIA 23298 U S A

CAVOGRAPHY IN THE MANAGEMENT OF MALIGNANT ABDOMINAL TUMORS

S O HIETALA H KANGARLOO and K RANNIGER

The tendency of malignant abdominal tumors most commonly renal carcinoma to invade the inferior vena cava is well known (ARDEKANI et coll 1971 DORR et coll 1973 MCCULLOUGH & TALNER 1974 NOVY et coll 1974 SKINNER et coll 1972) Recently the angiographic demonstration of intracaval tumor extension in cases of renal carcinoma hepatocellular carcinoma and retroperitoneal sarcomas was further emphasized (GREGG et coll 1975) Although demonstration of the so-called striated vascular appearance along the course of the renal vein or inferior vena cava indicates intravenous tumor invasion (MCCULLOUGH & TALNER) absence of this appearance does not exclude venous involvement (FERRIS et coll 1968 MCCOY et coll 1969) Therefore the pertinent way to confirm or exclude venous tumor involvement is to demonstrate directly the inferior vena cava and its tributaries In cases of complete occlusion of the inferior vena cava the superior extent of the tumor invasion should be determined by catheterizing the superior vena cava Such a thorough preoperative angiographic evaluation should be mandatory for modern surgical management (MCCULLOUGH & TALNER) It seems indicated to further emphasize the importance of phlebography not only of the inferior but also of the superior vena cava on the basis of [illegible] cases observed

The clinical symptomatology and the roentgenologic findings in cases of non neoplastic or neoplastic involvement of the inferior vena cava vary according to the level of obstruction or occlusion The inferior vena cava may be divided into three

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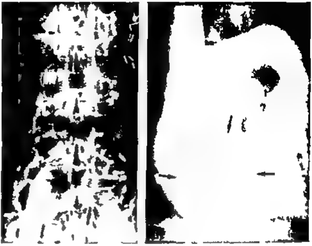

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Fig 1 Carcinoma of the left kidney in a 45 year old male operated upon and irradiated 6 months previously a) Inferior phlebography extensive tumor involvement of both common iliac veins Collateral circulation mainly through ascending lumbar veins b) Injection into the superior vena cava The tumor mass (→) fills the right atrium and the atrial wall seems to be infiltrated

segments the lower third below the renal veins the middle third between the renal and hepatic veins and the upper third above the hepatic veins This division is justified from physiologic as well as from pathologic points of view (LEITER 1966) Renal and hepatic veins add a large volume of blood to the inferior vena cava and therefore the flow volume increases suddenly at the level of these veins The increased blood flow probably prevents the propagation of thrombosis from pelvic veins to the middle and upper thirds of the inferior vena cava These physiologic facts have important radiographic implications Thus a thrombosis above the renal vein is most probably neoplastic as is a thrombosis in the lower third of the inferior vena cava in cases of patent pelvic veins These physiologic and pathologic aspects are of decisive importance concerning both the technique of examination and the principles of assessment of the films Bilateral percutaneous catheterization of the femoral veins has to be performed and simultaneous injections made With this method both external and common iliac vessels and the inferior vena cava are filled and streaming defects are minimized or eliminated For evaluation of the inferior vena cava it is important to take supine and right posterior oblique films routinely

The clinical symptomatology in most of the 6 cases was vague and nonspecific However 2 of the patients had edema of the legs and in one patient (Fig 4) dilated superficial abdominal veins were found at the exploratory laparotomy

It has been reported that occlusion of the middle third (Fig 4 b) of the inferior vena cava and renal veins may be the cause of massive albuminuria in such cases a result of increased renal venous pressure secondary to obstruction of the inferior vena cava above the renal veins Hepatomegaly ascites and abdominal pain indicate involvement of the upper third of the inferior vena cava (Fig 5 c) and hepatic veins (LEITER) It is evident that extensive collateral pathways may prevent the appearance of such characteristic occlusive symptoms and signs

Fig. ... Carcinoma of the left kidney in a 5.. year-old male a) Selective left nephroangiography late arterial phase Tortuous and irregular widened arteries in the lower two-thirds of the kidney A network of parallel collateral channels are filled along the course of the left renal vein b) Inferior vena cava Right posterior oblique view Total occlusion of the vein at the expected level of the left renal vein c) Injection into the right atrium where an irregular tumor mass is demonstrated (→) d) Superior vena cava Almost total occlusion of the vein and an extensive collateral flow through the azygos hemiazygos and internal mammary veins

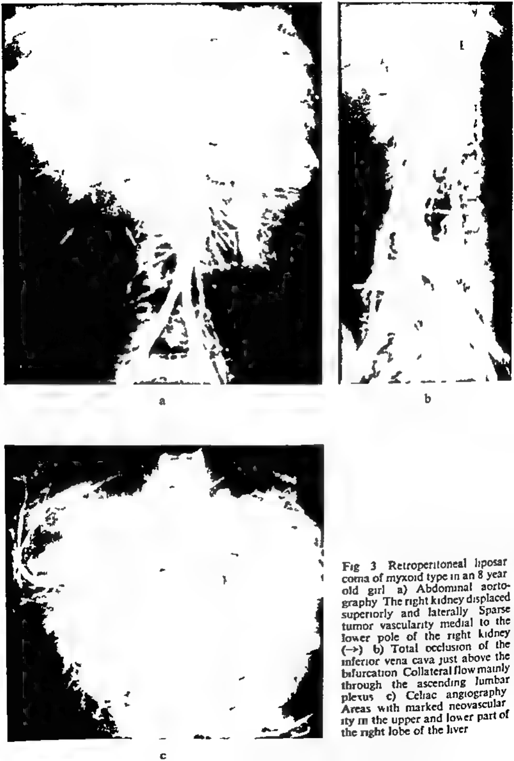


Fig 3 Retroperitoneal liposarcoma of myxoid type in an 8 year old girl a) Abdominal aortography The right kidney displaced superiorly and laterally Sparse tumor vascularity medial to the lower pole of the right kidney (→) b) Total occlusion of the inferior vena cava just above the bifurcation Collateral flow mainly through the ascending lumbar plexus c) Celiac angiography Areas with marked neovascularity in the upper and lower part of the right lobe of the liver

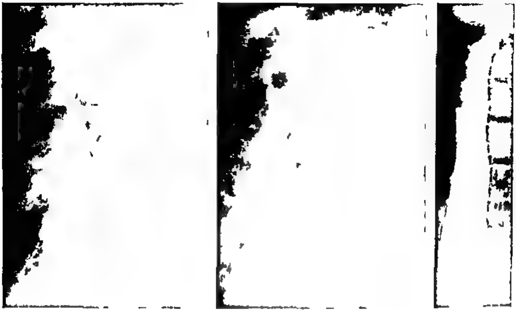
a b c

Fig 4 Carcinoma of the right kidney in a 53 year-old female a) Selective right nephroangiography early capillary phase Extremely widened and tortuous vessels of varying caliber in the upper half of the kidney A network of vessels (→) filled along the renal vein and inferior vena cava b) Total occlusion of the inferior vena cava at the expected level of the right renal vein with filling of widened lumbar collaterals c) Injection into the superior vena cava Filling of the vein and the right side of the heart Extensive tumor growth through the right atrium to the vein The lateral atrial border up to the superior vena cava is irregular indicating intramural tumor infiltration

Renal tumors are most commonly associated with tumor invasion into the inferior vena cava In the present material renal tumors were found with the same frequency on both right and left sides even though the right kidney is more commonly the site of tumor invading into the vena cava (NEY 1946) due to a shorter length of the right renal vein

The right atrium was involved in 3 of 4 cases with renal cell carcinoma According to the literature (ARDEKANI et coll) right atrial involvement occurs in approximately 25 to 40 per cent of the cases with involvement of the vena cava Tumor growth in the right atrium may clinically simulate tricuspid valvular disease as in 2 of the present cases

It appears also that a striated vascular appearance (FERRIS et coll) in the position of renal veins or the vena cava indicates intravenous tumor extension either to the renal veins alone or to the renal veins and inferior vena cava Evidently the absence of this sign does not exclude the presence of intravenous tumor involvement There



a b c

Fig 5 Hepatoblastoma in a 55 year old female Celiac angiography a) Arterial b) capillary phase Marked neovascularity throughout the right lobe of the liver c) Inferior vena cava Irregular filling defect extending from the upper part of the vein into the right atrium

fore the only accurate way of diagnosing or excluding tumor extension into renal veins or the inferior vena cava is to demonstrate these veins directly

Examination of the inferior vena cava is also useful in evaluating retroperitoneal tumors as exemplified by the case of retroperitoneal liposarcoma (Fig 3) which is a very rare type of tumor in children with only 4 cases previously reported in the literature (PEEPLES & HAZRA 1976) The angiographic appearances are typical for most retroperitoneal sarcomas The arteries may be normal or almost normal but the veins are unmistakably abnormal with extensive tumor growth Radiologically it is not always possible to decide whether the abnormalities are caused by extrinsic compression or actual invasion of the vena cava It appears from the discussion that the veins are much more vulnerable than the arteries in different types of tumors An examination of the inferior vena cava should therefore be a routine procedure for the preoperative assessment of abdominal tumors in children The usual percutaneous femoral puncture method of performing cavography in adults may be modified in infants and small children by using the dorsal vein of the foot at the time of urography (RANNIGER & SALDINO 1968) However non filling of the inferior vena cava in children should be interpreted with extreme caution since the effect of increased intra abdominal pressure by crying may mimic a total occlusion of the inferior vena cava caused by tumor invasion

The tendency of malignant tumors of the liver to invade portal veins as well as the inferior vena cava has been recognized previously (GREGG et coll.) and the value of hepatic and superior mesenteric angiography in establishing the diagnosis of hepatoma has been stressed in previous reports (NOVY et coll.). The importance of examination of the inferior vena cava in assessing operability of hepatoma has been discussed only recently when hepatic resection has become possible. It must be further emphasized that this examination, sometimes in addition to hepatic and portal phlebography, offers invaluable information of the extension of the tumor before hepatic resection. As pointed out, these tumors may involve the upper third of the inferior vena cava and extend superiorly to involve the right atrium.

SUMMARY

Six cases of malignant abdominal neoplasm with extensive tumor involvement of the veins form the basis of this report. One case was a child with retroperitoneal liposarcoma. Proper therapeutic management in these cases was dependent upon a complete angiographic evaluation including cavography. This procedure is virtually without complications and should therefore be done routinely in cases of abdominal neoplasms for evaluation of the operability, to confirm the angiographic findings indicating intravenous tumor invasion or extravenous compression, and as a primary examination in the assessment of possible or known abdominal tumors in children.

ZUSAMMENFASSUNG

Sechs Fälle mit einem malignen Abdominaltumor und mit Tumoreinwachsen in die Venen werden berichtet. Ein Fall war ein Kind mit einem retroperitonealen Liposarkom. Die richtige therapeutische Behandlung dieser Falle war abhangig von einer kompletten angiographischen Untersuchung einschliesslich Kavographie. Die Kavographie ist praktisch ohne Komplikationen und sollte deshalb routinemassig bei Fallen von Abdominaltumoren zur Feststellung der Operabilitat, um die angiographischen Befunde zu bestatigen, welche auf ein intravenoses Wachstum oder eine Kompression der Venen hinweisen, und als eine primare Untersuchung zur Feststellung eines moglichen oder bekannten Abdominaltumors von Kindern vorgenommen werden.

RESUME

Ce travail est basé sur 6 cas de tumeur abdominale maligne avec atteinte tumorale etendue des veines. Un de ces cas était un enfant atteint de liposarcome rétroperitoneal. La conduite therapeutique adequate dans ces cas depend d'un bilan angiographique complet comprenant la cavographie. Cette technique n'entraine pratiquement pas de complication et devrait donc etre exécutee systematiquement dans les cas de tumeur abdominale pour apprécier l'opérabilité, pour confirmer les signes angiographiques indiquant une invasion tumorale intraveineuse ou une compression extraveineuse et comme examen primaire dans le diagnostic de tumeur abdominale possible ou connue chez l'enfant.

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FROM THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY RADIOPHYSICS PHYSIOLOGY AND MEDICAL BIOPHYSICS UNIVERSITY HOSPITAL, UNIVERSITY OF UPPSALA S 750 14 UPPSALA SWEDEN

MEASUREMENTS OF TOTAL AND REGIONAL RENAL BLOOD FLOW BY VIDEODENSITOMETRY

U ERIKSON P G LINDGREN P O LÖFROTH G RUHN and M WOLGAST

In connection with selective nephroangiography the amount of contrast medium within the kidney was measured by a videodensitometric method The purpose was to determine the blood flow characteristics both with respect to the total and the regional flow within different regions of the kidney

Methods and Material

Videodensitometry In principle the technique is the same as that of conventional densitometry in which the amount of contrast medium located within a certain area is measured as the degree of blackening of the roentgen film In videodensitometry as presented here the photographic density is registered by an image intensifier the signal of which is fed to a videotape recorder The videosignal is then analysed by a videovolumeter (BJORK et coll 1974) In the present set up a frequency of 25 frames/s is used The videorecording appears on a TV screen (Fig 1) The area of interest is outlined by a light pen The method allows registration of indicator dilution curves from a whole organ or parts of it—in this case the kidney The procedure is easily and rapidly carried out in conjunction with a selective nephroangiography and requires only half the amount of contrast medium needed in conventional densitometry (ERIKSON et coll 1965)

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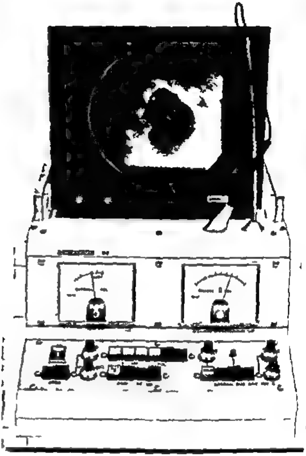


Fig 1 The videovolumeter below with two channels for simultaneous measurement The videoangiogram appears on the monitor above and the area in this case a cortical segment is outlined by the light pen

Isotope technique The total renal blood flow was also measured by the ^{133}Xe wash out method For this purpose 0 4 to 0 5 mCi was suspended in 1 ml of saline and injected as a bolus into the catheter in the renal artery The gamma radiation was recorded by a collimated scintillation spectrometer with 5 cm NaI crystal The distance from the crystal to the orifice of the cylindric collimator was 8 cm The position of the kidney was determined with an image intensifier TV system The counting rate was recorded on a linear writer Simultaneously counts were sampled during two second intervals and recorded on a teletype printer The whole recording was discontinued after 6 to 7 minutes For the blood flow estimation a two compartment model was used i e the curve was treated as a biexponential curve The calculation was performed with a Hewlett Packard 9820 A desk computer For comparison between the isotope and videodensitometric techniques, the values obtained from the first compartment were used The blood flow (F) was then calculated as follows

$$F = 0.7 \log 2/t_{1/2}$$

Table

Clinical material

Age	Sex	Flow (ml/min and g tissue) Xe	Video	Clinical symptoms or diagnosis	Radiography
49	F	3 76	3 03	Hypertension	Normal
65	F	2 50	2 91	Haematuria	Normal
69	F	2.95	2 91	Abdominal pain	Normal
58	M	3 31	2 38	Haematuria	Normal
72	F	2 40	2 61	Hypertension	Normal
4[illegible]	M	3 15	3 19	Hypertension	Normal
59	M	3 03	2 91	Abdominal pain	Renal cyst
54	M	1 95	1 49	Transplanted kidney	Transplanted kidney
64	F Right	2 48	3 30	Carcinoma left kidney	Carcinoma left kidney Right normal
74	M Right	2 71	2 83	Prostatic carcinoma	Normal
74	M Left	4 29	4 17	Prostatic carcinoma	Normal
54	M Right	2 95	1 92	Hypertension	Normal
54	M Left	3 88	3 80	Hypertension	Normal
51	F Right	2 88	2 56	Lung tumor	Normal
51	F Left	3 30	3 61	Lung tumor	Normal
61	M	3 84	3 85	Mesothelioma right lung	Normal
61	M	2 52	3 57	Trauma	Local infarction?
80	M	3 30	1 95	Prostatic carcinoma	Normal
63	M	3 46	3 80	Hypertension	Normal
41	F	2 91	2 30	Hypertension	Fibromuscular hyperplasia
36	F	2 88	2 30	Hypertension	Normal

where 0 7 is the partition coefficient (LADEFOGED et coll 1965) and $t_{1/2}$ the half time of the exponential decay curves

Animal experiments The experiments were carried out on 3 dogs weighing between 20 and 26 kg They were anaesthetized with Nembutal in a dose of [illegible] 5 mg/kg body weight The animals were intubated to ensure a free airway and were allowed to breathe spontaneously The left renal artery was catheterized from the left femoral artery using an Odman catheter The renal vein was catheterized from the left femoral vein also with an Ödman catheter the position of the catheters was checked to make sure that blood was flowing freely

Ten μCi of ^{125}I labelled Angiografin were mixed with Angiografin (Schering West Germany) and approximately 2 ml of the mixture were injected as a bolus through the catheter into the renal artery

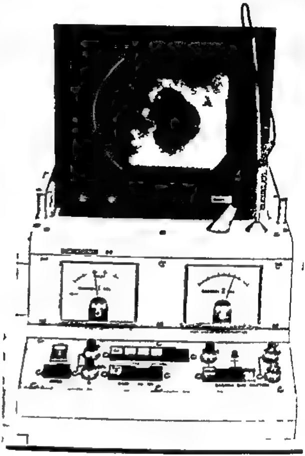


Fig. 1 The videovolumeter below with two channels for simultaneous measurement The videoangiogram appears on the monitor above and the area in this case a cortical segment is outlined by the light pen

Isotope technique The total renal blood flow was also measured by the ^{133}Xe wash out method For this purpose 0 4 to 0 5 mCi was suspended in 1 ml of saline and injected as a bolus into the catheter in the renal artery The gamma radiation was recorded by a collimated scintillation spectrometer with 5 cm NaI crystal The distance from the crystal to the orifice of the cylindric collimator was 8 cm The position of the kidney was determined with an image intensifier TV system The counting rate was recorded on a linear writer Simultaneously counts were sampled during two second intervals and recorded on a teletype printer The whole recording was discontinued after 6 to 7 minutes For the blood flow estimation a two compartment model was used i e the curve was treated as a biexponential curve The calculation was performed with a Hewlett Packard 9820 A desk computer For comparison between the isotope and videodensitometric techniques the values obtained from the first compartment were used The blood flow (F) was then calculated as follows

$$F = 0\ 7 \log 2/t_{1/2}$$

at time t during a time interval dt is then calculated as h(t)dt The sum or rather the integral of all the different fractions is by definition equal to one

$$\int_0^{\infty} h(t)\,dt = 1$$

In practical experiments the h(t) function is obtained as

$$h(t) = F\ c(t)/M$$

where F is the blood flow to the organ in question c(t) the concentration of indicator obtained in the venous effluent at different times and M the total amount of indicator injected

The latter equation can be utilized for calculating the total blood flow which by integration becomes

$$\int_0^{\infty} h(t)\,dt = F \int_0^{\infty} c(t)\,dt/M$$

Since the left term is equal to 1 the flow (F) is calculated as

$$F = M \Big/ \int_0^{\infty} c(t)\,dt$$

As soon as the h(t) function is known the mean transit time $\bar{t}$ is easily calculated

$$\bar{t} = \int_0^{\infty} h(t)\,dt\ \ t$$

If then both the blood flow F and the mean transit time $\bar{t}$ are known the volume of distribution of the indicator (V_i) may be calculated

$$V_i = F\ \bar{t}$$

The h(t) function thus gives the distribution of transit times as analysed from the venous effluent The fractional residue located within the organ is then simply $1 - \int_0^t h(t)dt$ The latter function is often denoted H(t) The integral $\int_0^t h(t)dt$ is then the fraction that has left the organ up to time t From this relation the indicator dilution curve obtained by a videodensitometric method or equivalent alternative methods is described by the equation

$$I(t) = M\ E\left(1 - \int_0^t h(t)\,dt\right)$$

where I(t) is the amplitude of the output signal from the detector and E an efficiency factor of the system The height I_0 recorded immediately after the injection when no contrast medium has left the region is then

$$I_0 = M\ E$$

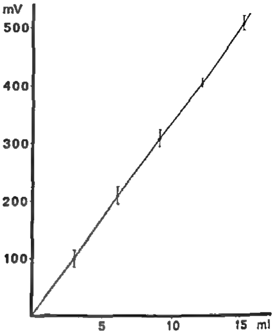


Fig 3 Model experiment with good linear correlation between the amount of con trast medium in a particular region and the voltage of the videovolumeter

The area (dA) of the curve produced during the passage of a certain fraction of the amount injected M h(t)dt is proportional to this amount and the transit time t

$$dA = M\ E\ h(t)dt\ t$$

The total area A is then

$$A = M\ E\int_0^{\infty} h(t)\,dt\ t$$

Dividing the area A by the initial height I_0 is obtained

$$A/I_0 = \int_0^{\infty} h(t)\,dt\ t$$

where $\int_0^{\infty} h(t)\,dt\ t$ is the mean transit time as before The above analysis is based completely on the assumption that the efficiency factor E operating soon after the injection will be equal to the mean efficiency operating throughout the production of the entire curve This means that the efficiency factor should be independent of where the indicator is located within the organ in question Moreover the efficiency should be linearly related to the amount present during the different times

In order to test the above assumption the videodensitometric signal was measured at varying amounts of contrast medium in an area (Fig 3) The relationship was linear The efficiency factor was also analysed in several areas and a heterogeneity of 5 to 10 per cent was found

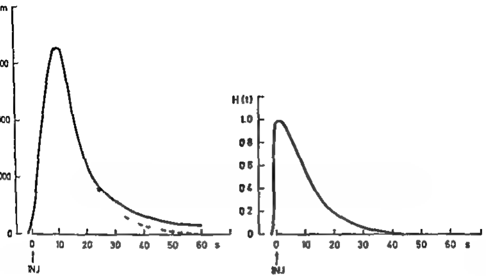
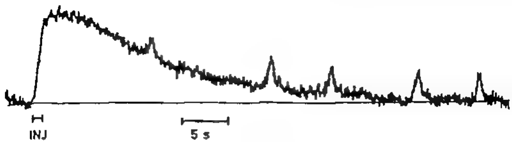


Fig. 4. Dog experiment. Isotope indicator dilution curve (left) as obtained from the renal venous effluent and the corresponding curve (right) for the residue of indicator within the renal parenchyma at different times. Flow = 2.1 ml/min g, $\bar{t}$ = 15.1 s, $V_{dist,tb}$ = 0.53 ml/g.

Results

Animal experiments. The results of a typical experiment are illustrated in Fig. 4. In the left panel the isotope indicator dilution curve, as obtained in the venous effluent, appears. In order to obtain the curve during a single circulation the descending part of the curve is extrapolated under the assumption of a monoexponential decay. The total renal blood flow, as obtained by dividing the amount of indicator injected by the area of the curve, was estimated to be 2.1 ml/min and gram kidney. The transit time was calculated to be 15.1 s. From these parameters the volume of distribution of the indicator could be calculated by multiplying blood flow by transit time. The curve will also permit calculation of the amount of indicator remaining in the renal parenchyma at different times. In practice this is performed by subtracting the number of counts obtained in the venous effluent up to the time in question, t, from the total number of counts obtained in the venous effluent, i.e. from time zero to infinity (ZIERLER 1962). The data are then normalized so that the total number of counts recorded is equal to 1. This curve, designated H(t), appears in the right part of Fig. 4. It should be emphasized that the curve to the left reflects the distribution of transit times as analysed from the venous effluent whereas the curve in the right hand panel gives the indicator residue within the renal parenchyma at different times. H(t) has a steep rise up to the figure of 1.0. It then remains constant for 2–3 s before falling towards zero. The corresponding curve as obtained by the videodensitometric method (Fig. 5) has the same rapid rise up to a plateau, whereafter it decreases seemingly monoexponentially towards zero. The H(t) function (Fig. 4, right part)



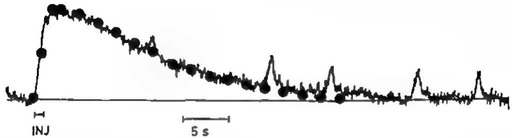


Fig 5 Dog experiment The upper curve was obtained by the videodensitometric method during the experiment illustrated in Fig 4 The same curve is shown below but the true amount of contrast medium indicated by black dots is superimposed on the densitometric curve The two curves are normalized to yield the same area It is evident that the shape of the curves are almost identical The small peaks are respiratory artefacts

is superimposed on the curve obtained by the videodensitometric method The areas of the two curves are adjusted to yield the same value The two curves are almost identical (Fig 5) This proves that the videodensitometric method faithfully reflects the true amount of contrast medium within the analysed parenchyma The mean transit time determined from the videodensitometric curve is thus the same as that obtained from the isotope indicator dilution curve i e 15 1 s The volume of distribution of the indicator will be the same as that generally recorded with inulin i e about 0 5 ml per ml and gram which is in fact verified in the series of dog experiments With the videodensitometric method the blood flow can thus be calculated to be about 2 ml/min and gram tissue

Clinical examinations The results of 21 determinations of total renal blood flow in patients are presented in the Table The total blood flow expressed as ml/min g kidney is given for both the ^{133}Xe wash out method and the videodensitometric techniques With the former method it ranged from 1 95 to 4 29 ml/min and g tissue and with the latter from 1 49 to 4 17 ml/min and g tissue The lowest values were obtained for a transplanted kidney (Table)

The values obtained by the isotope and video methods were essentially the same

The mean value for the Xe wash out method was 3 0±0 ▮ ml/min g and for the video method 3 0±0 7 ml/min ▮ The range of difference on paired comparison between the two methods was ±0 07 to ±0 56 corresponding to a scatter of 18 per cent *thus there was no significant difference between the methods*

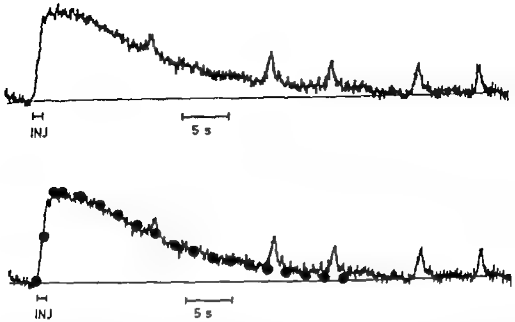
Discussion

Both the videodensitometric and the ^{133}Xe wash out methods measure time In the present investigation this was expressed as the mean transit time with the video densitometric method and as half time with the ^{133}Xe wash out method In order to calculate blood flow the volume of distribution of the indicators must be known In the ^{133}Xe wash out method this factor is influenced by the fat content of the kidney and the haematocrit of the blood and in the videodensitometric method it is related to the extracellular volume which may vary The Xe wash out method only allows calculation of the total renal blood flow whereas the videodensitometric method permits determination of both the total and regional flows

As regards efficiency with the ^{133}Xe wash out method this is obviously influenced by the position of the indicator in relation to the detector center In the videodensitometric method the efficiency was found to be linearly related to the amount of contrast medium However it should be emphasized that the efficiency varied somewhat from one region of the kidney to another Previous model experiments indicated that the efficiency at the periphery of the kidney was about five per cent higher than the average efficiency This discrepancy from the ideal condition is negligible in relation to the over all accuracy of the method In practical experiments on dog kidneys *this inhomogeneity of the efficiency proved to be of no significance*

In the clinical series the measured total renal blood flow was approximately 3 ml/min and g tissue which would mean 900 ml/min for the two kidneys i e figures which are generally accepted as the true renal blood flow under normal conditions The comparison between the videodensitometric and the Xe wash out methods showed no significant difference except in a few cases Thus the total renal blood flow in one patient (Table) was 1 95 ml/min and g tissue with the former method as compared with 3 3 with the latter The latter value is probably an overestimation considering the high age of the patient (80 years) The lowest blood flow value was obtained in a transplanted kidney (Table) as might be expected However the two methods showed approximately the same value

A clear limitation of both methods is that they measure a time factor In the video densitometric method the mean transit time is calculated and in the ^{133}Xe wash out method the time lapse of the curve is analysed by half time $t_{1/2}$ The half time is easily converted to mean transit time by dividing it by log 2 The volume of distribution of the indicator within the monitored volume has to be known to calculate blood flow In the ^{133}Xe wash out method this volume is influenced by the fat content of the tissues and also by the haematocrit In the videodensitometric method the



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NON IONIC AND DIMERIC CONTRAST MEDIA IN CORONARY ANGIOGRAPHY

Experimental investigations in dogs

L BJORK P ELDH and S PAULIN

Modern contrast media used in clinical coronary angiography generally have low toxicity but side effects some of them serious have encouraged continuous search for less toxic contrast media Because osmolality seems to be one of the major determinants of the side effects dimeric (BJÖRK et coll 1969 1971) and non ionic (ALMÉN 1973 a b) contrast media with low osmolality have been developed

The effects of currently used monomeric contrast media on the ECG and the left ventricular pressures were compared with those of a dimeric (iozomic acid) and a non ionic contrast medium (metrizamide) during coronary angiography in dogs

Material and Methods

Thirty two mongrel dogs were used 20 of them weighed 20 to 25 kg and the other 12 9 to 11 kg The dogs were anesthetized with intravenous sodium thiopental intubated and heparinized A pigtail catheter introduced through one of the femoral arteries was positioned in the left ventricle for continuous recording of left ventricular pressure A suitably shaped catheter was manipulated from the other femoral artery into the left main coronary artery The left ventricular pressures were recorded using a Statham strain gauge manometer The pressures as well as the ECG (lead 2) were recorded continuously before during and after injections

Two contrast media were compared in each dog after injections in increasing dos

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age One contrast medium was injected first in one dog and the other first in the next dog etc in each series of experiments In the larger animals 3 6 and 12 ml were injected at intervals The rate of injections was kept constant at 1 ml/s with a Harvard injector or an automatic pressure injector In the smaller animals 1 5 3 and 6 ml were injected and the rate of injection was reduced to 0 5 ml/s The injections were monitored with television fluoroscopy and recorded on 35 mm cine or 70 mm films With these injection rates there was good filling of the left coronary artery branches and no reflux to the aorta

The compositions of the contrast media used in the investigation were as follows

(1) Metrizamide (dry powder) dissolved in water to 280 300 or 370 mg I/ml (Nyegaard Oslo Norway)

(2) Isopaque Cerebral 280 mg I/ml containing 591 mg meglumine metrizoate and 11 3 mg calcium metrizoate per ml (Nyegaard Oslo Norway)

(3) Isopaque Coronar 370 mg I/ml containing 101 mg sodium 656 5 mg meglumine and 11 3 mg calcium metrizoate per ml (Nyegaard Oslo Norway)

(4) Meglumine iozomate 300 mg I/ml (Pharmacia Uppsala Sweden)

(5) Iozomate solution 300 mg I/ml containing sodium meglumine and calcium ions in the same proportions as in Isopaque Coronar (Pharmacia Uppsala Sweden)

(6) Renografin 76% 370 I/ml meglumine/sodium diatrizoate (Squibb & Sons Princeton N J U S A)

(7) Hypaque M 75% 385 mg I/ml meglumine/sodium diatrizoate (Wintrop Laboratories New York N Y U S A)

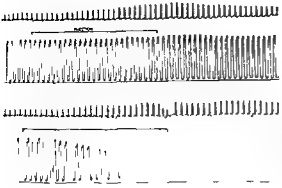
Changes in heart rate the occurrence of extrasystoles ventricular fibrillation and changes in the ST segments and QRS complex were noted and the magnitude and the duration of such changes were compared Changes in the left ventricular systolic and diastolic pressure were expressed as the percentage of change from pre injection values after each separate injection The magnitude and the duration of the pressure changes were compared

Results

(1) Comparison of metrizamide 280 mg I/ml and Isopaque Cerebral (6 dogs contrast doses 3 6 and 12 ml) Left ventricular pressures were only slightly affected at all dose levels In 8 dose pairs the pressure effects were similar with both media in the other 10 dose pairs the effects on left ventricular pressure were more marked after Isopaque Cerebral than after metrizamide

The effects on the ECG were similar in 4 dose paired injections In the other 14 Isopaque Cerebral produced more changes including 2 instances of ventricular fibrillation one occurred after an injection of 6 ml and one after 12 ml

(2) Comparison of Renografin 76% and metrizamide 370 mg I/ml (4 dogs contrast doses 3 6 and 12 ml) In all injections at all dose levels Renografin 76% produced marked changes both in left ventricular pressures and the ECG (Figure) In one dog ventricular fibrillation occurred after 12 ml of Renografin



Differences in the effects on left ventricular pressure and the ECG of two contrast media during left coronary angiography in the dog Top 12 ml metrizamide (370 mg I/ml) Bottom 12 ml Renografin 76 (370 mg I/ml)

(3) Comparison of Hypaque M 75% and Isopaque Coronar (3 dogs contrast doses 3 6 and 12 ml) At the 3 ml level no significant difference between the two media was found In all injections of 6 and 12 ml doses Hypaque 75% produced more marked changes in left ventricular pressures and the ECG than Isopaque Coronar Ventricular fibrillation occurred in one dog after 12 ml of Hypaque

(4) Comparison of metrizamide 370 mg I/ml and Isopaque Coronar (8 dogs contrast doses 3 6 and 12 ml) The effects on the pressures and on the ECG were generally slight or moderate and varied At 3 ml no difference in effects on left ventricular pressures occurred At the 6-ml level metrizamide had more effects in 3 cases no difference was found in the other 5 animals At the 12 ml level Isopaque Coronar had more effect in 5 instances m trizamide had more effect in 2 and no difference was found in one

On the ECG more effects were seen in one animal after Isopaque Coronar and in one animal after metrizamide at the 3 ml level No differences were found in the other animals at this level At the 6 ml level more effects were seen in one animal after Isopaque Coronar At the 12 ml level Isopaque Coronar induced more changes in 4 animals and metrizamide in one animal

(5) Comparison of metrizamide 300 mg I/ml and iozomate meglumine solution (6 dogs contrast doses 1 5 3 and 6 ml) No difference was found in the changes of left ventricular pressures between the two contrast media In 2 instances there were more severe ECG changes after metrizamide but in 5 instances there were more severe changes after iozomic meglumine (including 2 instances of ventricular fibrillation at the 6-ml dose level) In the remaining 11 instances there was no difference among the ECG responses

(6) Comparison of metrizamide 300 mg I/ml and iozomate meglumine sodium calcium solution (6 dogs contrast doses 1 5 3 and 6 ml) The effects on left ventricular pressure and the ECG were generally minimal and similar with both media at all dose levels However 2 dogs developed ventricular fibrillation one after 6 ml of metrizamide and one after 6 ml of iozomic solution

Discussion

The experimental technique comparing the effect of contrast media on the heart in coronary angiography has been used previously (KAFTORI & PAULIN 1974) It has the advantage of using relatively few injections (only 6) in each animal It also minimizes the effects of variations in cardiac output coronary artery flow and anatomy which may considerably influence the effects of contrast medium injections

When differences in the ECG or left ventricular pressure follow injections of two contrast media at the same dose level in the same dog with a 10 min interval it is reasonable to assume that the effects of the two media are different When no difference is found it may be argued that the method is too crude to detect a possible difference With dose levels three to six times higher than those used in clinical coronarangiography however this seems unlikely When the effects of the two contrast media compared were varying or equivocal no clear conclusion can be drawn a larger series of experiments would be necessary to prove any difference

In these experiments metrizamide was found to affect the ECG and left ventricular pressures less than conventional contrast media for coronary angiography This confirms previous experiments (ALMÉN 1973 b TRAGÅRDH et coll 1975)

It has previously been shown that the addition of sodium ions and calcium ions to conventional contrast media decreases their effects on heart function (SALVESEN et coll 1967 JACOBSSON & PAULIN 1967 BJÖRK 1967) In the present experiments the effect on left ventricular pressures or the ECG were not clearly different when comparing the non ionic metrizamide solution with a monomeric contrast medium (Isopaque Coronar) containing sodium and calcium ions Similar results using slightly different experimental technique have been reported elsewhere (TRÄGÅRDH et coll) In those experiments the addition of 140 mEq/l sodium 4 2 mEq/l potassium 5 1 mEq/l calcium and 3 2 mEq/l magnesium ions in the form of metrizoate to the metrizamide solution had no clear advantage Howev r the addition of 13 2 mEq/l of calcium chloride to the metrizamide solution reduced the effect on ventricular contractility and aortic pressures This solution also had less effect on these parameters than a metrizamide solution containing 155 mEq/l sodium and 18 5 mEq/l calcium

A pure meglumine solution of the dimeric iozomic acid had more effect on the ECG than metrizamide whereas the effects on left ventricular pressures were minimal and similar with both media When sodium and calcium ions were added to the iozomic solution no difference between this solution and metrizamide was found This again shows the favorable effect of adding sodium and calcium ions in suitable quantities to ionic contrast media used in coronary angiography

In previous investigations on patients (BJÖRK et coll 1971) the dimeric iozomic solution showed less effect on the ECG than the corresponding monomeric medium It appears that the non ionic metrizamide when compared at the same iodine con

centration has less effect on the ECG and left ventricular pressure than monomeric ionic contrast media and that the dimeric iozomic acid has a position between the two However addition of sodium-calcium ions to the ionic media reduced these differences This brings the advantage of metrizamide as a medium for coronary angiography into question

The high viscosity of both metrizamide and iozomic solutions theoretically should create adverse effects of its own (KAFTORI & PAULIN 1975) but in these and other experiments (TRAGARDH et coll) this seems not to be the case The high viscosity presented no technical difficulties with the injection technique and low injection rates used in this investigation

To simulate clinical coronary angiography, metrizamide was injected manually with iodine content of 370 mg/ml and 300 mg/ml through size 7 Fr (2 3 mm) Judkins coronary artery catheters (Cordis) with the solutions at room temperature and heated to 37 C With the 370 mg I/ml concentration at room temperature (25 C viscosity 21 0 cs) only 1 9 ml/s could be delivered on the average This is usually not enough to replace blood flow in coronary arteries in adult patients When warmed to 37 C (viscosity 11 6 cs) an average injection rate of 3 8 ml/s was achieved but frequent problems with sticking of the syringe were encountered With the 300 mg I/ml concentration at 25 C the average injection rate was 3 8 ml/s similar rates were achieved with the 300 mg I/ml iozomic meglumine sodium and calcium solution The use of 8 Fr (2 7 mm) Judkins catheters would of course permit higher injection rates

Acknowledgement

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SUMMARY

A dimeric contrast medium (iozomic acid) and a non ionic contrast medium (metrizamide) were used for selective coronary angiography in dogs They were found to have less effect on left ventricular pressures and the ECG than conventional contrast media

ZUSAMMENFASSUNG

Ein dimeres Kontrastmittel (Iozomsaure) und ein nicht ionisiertes Kontrastmittel (Metrizamid) wurden zur selektiven Koronarangiographie bei Hunden verwendet Es wurde gefunden dass diese einen geringeren Effekt auf den Druck des linken Ventrikels und das EKG als konventionelle Kontrastmittel haben

RESUME

Les auteurs ont utilisé un moyen de contraste dimere (acide iozomique) et un moyen de contraste non ionique (métrizamide) pour l angiographie coronaire selective sur des chiens Ces moyens de contraste ont moins d influence sur les pressions ventriculaires gauches et les ECG que les moyens de contraste habituels

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POLYCYSTIC DISEASE OF THE LIVER

Angiographic diagnosis

BIRGITTE BRUN and JORN PALBOL

Polycystic disease of the liver is frequently associated with cystic changes in other organs most frequently in the kidneys Whereas the renal condition often causes the patient to seek medical advice the cysts of the liver are usually an incidental finding at operation or autopsy In a few patients symptoms or signs from the liver dominate It is an advantage for these patients that the diagnosis be established without exploratory laparotomy as the condition per se does not require treatment

Incidence and Symptoms

Polycystic disease of the liver is a rare condition in a material of [illegible] 141 autopsies ACKMAN & RHEA (1931) found 11 cases The incidence of polycystic renal disease [illegible] autopsy as given in the literature varies between 1 351 (BELL 1950) and 1 773 (DALGAARD 1957) Generally 20 to 30 per cent of the patients with cystic kidney disease have cysts in the liver while conversely 50 per cent of patients with cystic livers have polycystic kidneys (COMFORT et coll 1952 DALGAARD) Cystic kidney disease has a uniform sex distribution while cystic disease of the liver occurs four times as frequently in females as in males (COMFORT et coll PELTOKALLIO 1970) Polycystic disease of the liver and kidneys [illegible] a hereditary condition although the

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Fig 1 Case 1 Coeliac angiography Elongated stretched arteries in a greatly enlarged liver No tumour vessels

mode of inheritance is uncertain (DALGAARD) Frequently the same disease is encountered in relatives of the patients (PELTOKALLIO ØRBECK 1959) The prognosis in polycystic disease of the kidneys is poor Recurrent renal infections often occur causing hypertension and haematuria and resulting in renal insufficiency on account of encroachment of cysts on functioning renal tissue As a rule the diagnosis is established in the fourth decade of life By contrast polycystic disease of the liver is usually symptom free Although the condition is congenital the clinical manifestations rarely appear before the age of 40 to 50 years (COMFORT et coll · PELTOKALLIO et coll 1967) Presenting symptoms are frequently due to pressure on neighbouring organs Patients complain of pressure and distension of the upper abdomen and infrequently of pain resembling gallstone colic Rarely complications in the form of rupture haemorrhage portal hypertension with oesophageal varicosities jaundice or malignant degeneration have been described (SHERLOCK 1968 PELTOKALLIO) The liver function is almost invariably normal The size of the liver may vary from normal to greatly enlarged with the liver occupying practically the entire abdomen The liver surface is nodular on palpation

Prognosis and Treatment

Polycystic liver disease runs a benign course and the prognosis depends upon the associated renal condition if present In occasional cases the hepatomegaly causes such severe pressure symptoms that puncture with evacuation of cyst fluid mar

Fig 2 Case 2 Cholecystography Indentations into the gallbladder

supialization or extirpation of the cysts prove necessary As a rule treatment is not indicated (SHERLOCK) but some authors recommend more active treatment of cysts in the liver (JONES et coll 1974) On the other hand polycystic disease of the kidney leads most frequently to such severe renal insufficiency that prolonged haemodialysis and renal transplantation become necessary While it is desirable to recognize concurrent cystic liver disease in these patients and check the liver function regularly this component of the syndrome should be regarded as benign It is not a contra indication to haemodialysis or transplantation

Material

The syndrome of cystic liver and polycystic kidneys was established by angiography in 3 women aged 20 to 50 years 2 with hepatomegaly In one of the patients supplementary isotope scanning and ultrasonic examination were carried out which corroborated the diagnoses Two of the 3 patients were members of families with known polycystic disease

Case reports

Case 1 A woman aged 46 without any history of renal disease was admitted to hospital on account of fatigue and increasing abdominal size The abdomen was distended and the epigastric region bulged The liver was grossly enlarged and filled the right side of the abdomen its caudal margin could be palpated on gynaecologic exploration The surface was nodular Laboratory tests including liver function tests and serum creatinine were normal The gallbladder was displaced caudally and medially at cholecystography The stomach was displaced to the left and the liver caused a smooth impression on the lesser curvature At coeliac angiography elongated stretched arteries in the greatly enlarged liver were observed but no pathologic vessels (Fig 1) In the parenchymatous phase numerous round contrast defects of up to 2 cm in diameter were observed scattered throughout the organ Selective bilateral nephroangiography demonstrated typical large cystic kidneys with elongated and curved arteries Numerous well delineated round areas of up to 6 cm were observed in the parenchyma No tumour vessels were recognized The appearances were typical of polycystic liver and kidney disease Explorative laparotomy was not undertaken

Fig 3

Fig 4

Fig 3 Case 2 Coeliac angiography Coeliac and pancreaticoduodenal arteries displaced towards the left

Fig 4 Case 2 Superselective angiography of the hepatic artery late arterial phase Arched hepatic arteries and round contrast defects of varying size in the liver parenchyma

Family history An older sister had died from another disease and autopsy had revealed polycystic kidneys and numerous cysts in the liver Explorative laparotomy had been undertaken elsewhere on a younger sister on account of hepatomegaly and revealed polycystic liver and kidneys

Case 2 A woman aged 50 with no history of renal disease In 1968 total hysterectomy was undertaken on account of uterine fibromata For two years she had experienced isolated attacks of sharp pain under the right costal margin On admission the general condition was good A tense possibly cystic swelling the size of a clenched fist was palpated under the right costal margin at the site of the gallbladder Laboratory tests including liver function tests and serum creatinine were normal Cholecystography Several indentations into the gallbladder (Fig 2) Radiography of stomach Rounded impression on the lesser curvature and displacement of the descending part of the duodenum towards the midline Coeliac angiography Coeliac and pancreaticoduodenal arteries displaced towards the left (Fig 3) Superselective angiography of the hepatic artery demonstrated elongated arched hepatic arteries and numerous round contrast defects of varying size in the liver parenchyma (Fig 4) No evidence of malignancy was found Bilateral selective nephroangiography suggested small cysts in the left kidney while the right kidney could not be assessed being displaced caudally and medially and compressed by the hepatic cysts Ultrasonic examination A large liver with numerous cystic focal processes multiple cysts in the right kidney and numerous small cysts in the left kidney Isotope scanning of the liver Multiple expansive lesions in the parenchyma compatible with but not specific of cysts A diagnosis of poly cystic disease in the liver and kidney was thus entertained and no explorative laparotomy was performed Family history The patient s mother had a polycystic liver established at laparotomy in another hospital

Fig 5

Fig 6

Fig 5 Case 3 Selective left nephroangiography late arterial phase Multiple expansive lesions throughout the kidney

Fig 6 Case 3 Coeliac angiography Right half of the liver is supplied from mesenteric artery via pancreatic arches Elongated thin arched vessels in the right lobe of the liver

Case 3 A woman aged 20 without known familial disposition to renal disease was admitted on account of recurrent urinary infections and a single episode of haematuria The general condition was good Neither the liver nor the kidneys were palpable Laboratory tests including serum creatinine were normal Urography indicated bilateral cystic kidneys Bilateral selective nephroangiography revealed typical large cystic kidneys with elongated vessels and a narrow residue of parenchyma (Fig 5) Coeliac angiography disclosed a developmental anomaly in that the right half of the liver was supplied from the mesenteric artery via the pancreatic arches Elongated thin arched arteries were observed in the right lobe of the liver (Fig 6) No tumour vessels were present The portal vein was displaced upwards and medially Diagnosis Polycystic kidneys with cyst formation also in the liver No operation was undertaken

Discussion

Cyst involvement of the liver is suggested when hepatomegaly is present in patients with known polycystic renal disease The object of angiography of the liver in these patients is to ensure that the liver disease being part of the syndrome is of a benign nature and thus of no consequence for future treatment of the cystic kidneys In patients without known renal disease nodular hepatomegaly primarily should suggest liver metastases

Polycystic renal disease is diagnosed as a rule at urography and the diagnosis may be confirmed by nephroangiography or ultrasonic examination Polycystic liver disease is more difficult to diagnose Occasionally conventional films of the abdomen reveal calcification in the liver cysts (PELTOKALLIO) but usually only

indentations of the liver on the surrounding organs. The right hemidiaphragm may be elevated and its mobility reduced. As in 2 of the present patients displacement of the stomach, duodenum, gallbladder and right flexure of the colon may be encountered. Notching of the gallbladder (Case 2) is considered a characteristic finding (SANDY 1965). Occasionally liver cysts may be seen during the nephrographic phase of urography (HATFIELD & PFISTER 1973). On angiography with selective injection of the contrast medium into the coeliac or hepatic arteries elongated vessels may be observed. The vessels curve around the cysts but there is no evidence of increased or abnormal vascularity. In the parenchymal phase round contrast defects corresponding to the avascular regions are observed. The cysts may be multiple or solitary. Solitary cysts are considered by many authors to be a localized manifestation of the polycystic disease (PELTOKALLIO).

Isotope scanning of the liver may reveal focal processes without activity but cannot differentiate between cysts and tumours not accumulating the isotope. Ultrasonic examination of the liver may demonstrate cystic lesions, probably with the same degree of confidence as angiography (MCCARTHY et coll. 1969).

Conclusion. Exploratory laparotomy can be avoided if a possible polycystic disease of the liver and kidneys is confirmed by angiography. The prognosis of the syndrome is determined by the renal lesion. Following detection of cystic disease of the liver the kidneys should be examined. Conversely, in patients with polycystic kidneys the liver should be examined so that doubts about the nature of the hepatomegaly, if present, need not arise.

SUMMARY

Three cases of the syndrome of polycystic disease of the liver and kidneys are presented. The definite diagnoses were established by means of angiography. Exploratory laparotomy was avoided. The incidence and symptoms of the syndrome and the diagnostic potentials of the methods of examination are reviewed. It is concluded that detection of either polycystic liver or kidney disease should initiate examination of the other component of the syndrome as well.

ZUSAMMENFASSUNG

Drei Fälle mit einer polyzystischen Erkrankung der Leber und der Nieren werden beschrieben. Die exakte Diagnose wurde mittels Angiographie festgestellt. Eine explorative Laparotomie wurde vermieden. Das Vorkommen und die Symptome dieses Syndroms und die diagnostischen Möglichkeiten der Untersuchungsmethoden werden zusammenfassend besprochen. Es wird festgestellt, dass die Entdeckung entweder einer polyzystischen Leber- oder Nierenerkrankung auch eine Untersuchung der anderen Komponente dieses Syndroms zur Folge haben sollte.

RÉSUMÉ

Présentation de 3 cas de syndrome de maladie polykystique du foie et des reins. Le diagnostic précis a été établi grâce à l'angiographie. La laparotomie exploratrice a été

évitée Les auteurs passent en revue la fréquence et les symptomes de ce syndrome et la valeur diagnostique des methodes d examen Ils concluent que la decouverte d une maladie polykystique soit hépatique soit renale doit entrainer un examen à la recherche de l atteinte de l autre composante de ce syndrome

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Book reviews

LES PIÈGES DIAGNOSTIQUES EN RADIOLOGIE PEDIATRIQUE By C Faure and A Coussement 163 pages with 210 figures Expansion Scientifique Paris 1975 Price F 120

This booklet belongs to a series of monographs published by the Annales de Radiologie It contains a collection of film reproductions illustrating some of the diagnostic pitfalls that may trouble the beginner in pediatric radiology Each trap is presented as a quiz followed overleaf by the answer and a brief explanatory comment

Potential diagnostic pitfalls in a wide sense of the term are almost innumerable and any choice of examples would be a matter of personal preferences The selection given here is concerned mainly with mistakes caused by artefacts and technical errors by the overlapping of various anatomic structures or by insufficient acquaintance with the normal features of the immature skeleton and internal organs These difficulties are dealt with also in current textbooks but the present volume provides a didactic survey suitable for elementary exercise

Georg Theander

ENDOSCOPIE ET BIOPSIE DE L INTESTIN By K Beck W Dischler M Helms W Oehlert Masson et Cie Editeurs Paris 1974

This book is an atlas with 685 illustrations 500 of them in colour contributed by many authors Except for the conventional radiography the diagnostic methods for the entire alimentary canal are treated

The book opens with a short description of the diagnostic methods and then goes on to present endoscopic photographs pathologic specimens and high-class electromicroscopic views for different diseases Unfortunately only a few roentgen films appear as a supplement to the short presentation of endoscopic retrograde cholangiopancreatography and colonoscopy It would have been of great value not only for radiologists but for others as well if the work had also included radiographic illustrations

More than half the book is devoted to diseases of the colon and principal stress is laid upon endoscopic and microscopic illustrations of diseases of the rectum The chapter on colonoscopy is admittedly short but on the other hand the pathologic changes in the colon do not differ greatly from those occurring in the rectum

Apart from the paucity of radiographic views the illustrations are excellent especially the endoscopic colour films

The atlas is mainly intended for gastroenterologists For radiologists working with colonoscopy it will prove a useful reference book

Nils Gabrielsson

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY GLOSTRUP UNIVERSITY HOSPITAL
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DOUBLE CONTRAST EXAMINATION OF THE STOMACH

An improved technique

S M Mohammed and V Hegedus

Conventional barium meals are often inadequate for the diagnosis of minute lesions of the stomach Double contrast examinations have a higher accuracy In some cases they may provide information not available endoscopically since there are no blind areas In addition extragastric lesions are better recognized

Since 1911 (von Elischer) different techniques for double contrast examinations have been introduced Nevertheless it is only in a few centres they are performed routinely One of the major reasons is that the introduction of the air or gas is either cumbersome and unpleasant to the patient or little effective

This communication reports a simple and effective method for introducing a controlled amount of air into the stomach simultaneously with the barium the method is suitable for routine use even in the busy general hospital

Technique

The patient arrives to the department fasting At least half an hour before the beginning of the examination Metoclopramide (Primperan Lundbeck) 10 to 20 mg is given intramuscularly

A side hole is made in an ordinary drinking straw with a needle of 0 7 mm diameter The patient is informed that the side hole makes it possible to sip both air and barium suspension simultaneously and the advantages of double contrast examination are made clear It is emphasised that some effort is needed to sip the barium suspension it is not as easy as to sip soft drinks The patient is also urged to sip continuously in big gulps In some cases the examiner must help the patient by putting a finger intermittently against the side hole until the patient is convinced that it is possible to use the straw

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The atlas is mainly intended for gastroenterologists For radiologists working with colonoscopy it will prove a useful reference book

Nils Gabrielsson

a b

Fig 3 Posterior gastric wall a) Supine position Areae gastricae in the antrum b) Left anterior oblique position in another patient Expanding lesion on the posterior wall Gastroscopy and biopsies confirmed malignancy

supine three exposures are made quickly in the right anterior oblique frontal and in the left anterior oblique positions This ensures adequate documentation of the antrum and the lesser and greater curvatures of the corpus Low tube potential (70–90 kV) is most appropriate (Fig 3)

Duodenal cap and the duodenal loop With the patient supine and the right side turned upwards films of the bulb and the duodenal loop are exposed using the same tube potential as for the posterior wall of the stomach (Fig 4) Films are also exposed with the patient prone

Cardia and fornix With the patient prone the couch is raised to 45 to 60 He is turned until a satisfactory view of the cardia and fornix is obtained and a film is exposed using high tube potential (Fig 5)

By then the effect of the hypotonic agent is usually over i e peristalsis appears The patient is brought to the erect position and compression films of the antrum and duodenal cap follow Furthermore the peristalsis of the whole stomach and duodenum is observed if needed Supplementary exposures are made according to actual needs

Material

This technique was used in 272 patients aged 11 to 88 years in fairly equal distribution 257 were randomly chosen among those attending the out and inpatient services

Fig 4

Fig 4 Supine right anterior oblique position Phrenulum of the duodenum demonstrated

Fig 5

Fig 5 Double contrast demonstration of the fornix and upper part of the corpus

The other 15 patients had primarily been examined by the conventional method which had given an uncertain result The first 140 patients were examined without use of pharmacologic adjuvants In the other patients Buscopan or Glucagon were used as short acting hypotonic agents to delay gastric emptying thus avoiding superimposition of barium filled bowels Buscopan was used in 112 patients and Glucagon in 20 In the 15 cases where a repeat examination was performed metoclopramide (Primperan) was given intramuscularly 1 to 2 hours before the double contrast examination (Fig 6)

The barium sulphate suspensions used were Baritop, Barosperse Barytgen or Mixobar In every patient a survey film of the air in the fornix (Magenblase) was exposed before and after sipping of the barium suspension for planimetric determination of the amount of air swallowed

Furthermore in all cases planimetry was made of the supine frontal view of the stomach to calculate the size of the part of the stomach outlined by double contrast in relation to the total stomach area as suggested by Doi (1972) This ratio was

Fig 6 Two hours after intra muscular injection of 20 mg metoclopramide Large polyp on the lesser curvature of the antrum (Contrast medium in the colon)

considered satisfactory when lying between 35 and 65 per cent since under 30 p r cent the areae gastricae (adenoid mucosal pattern of the stomach) are not sufficiently demonstrated and over 70 per cent the overdistended gastric wall may obscure some abnormalities

Results

Of the 272 examinations abnormalities were found in 68 patients 42 had benign ulcers 3 benign tumours 8 malignant tumours and 14 other abnormalities (post operative condition extra gastric lesion etc)

The quality of the examinations was estimated and related to the different typ s of barium media used (Table) Examinations classified as poor do not m^an that they were completely unsatisfactory They just did not fulfill the criteria s^t forth In all cases the diagnostic standard of the films was generally superior to that of conven tional barium meals Of the 68 diagnoses 62 were confirmed either by gastroscopy laparotomy or autopsy 2 were false positives (early gastric malignancy) 2 benign ulcers misdiagnosed for malignancy and 2 massive postoperative fibrosis after Bill roth I resection mistaken for malignant tumours

The criteria used to evaluate the effectiveness of the technique (1) Minimum in crease of 50 per cent of the area of the air filled fornix (Magenblase) after ingestion of barium sulphate suspension (2) The part of the stomach outlined by double con trast between 35 and 65 per cent (3) The lesser and greater curvature of the corpus and antrum outlined by double contrast (4) Areae gastrica^ of the antrum demon strated (5) The duodenum and oesophagus demonstrated by double contrast (6)

Table

Quality of the films in relationship to the different types of barium sulphate suspensions used

Contrast medium	No of patients	Quality of the examinations			
		Good		Poor	
		No	Per cent	No	Per cent
Mixobar	36	20	55 6	16	44 4
Barosparse	35	24	68 6	11	31 4
Barytgen	53	39	73 6	14	26 4
Baritop with straw	109	81	74 3	28	25 7
Baritop without straw	39	13	33 3	26	66 7
Total	272	177	66 2	95	33 8

Absence of air bubbles in the stomach after the ingestion of the contrast medium The examination was considered satisfactory if criteria 1 and 2 and at least three others were fulfilled

Discussion

Double contrast examination of the stomach is not new VON ELISCHER (1911) BAASTRUP (1924) VALLEBONA (1926) and LYSHOLM (1937) were aware of its significance Recent advances in the detection of early gastric malignancy and high correlation rate between radiography and fibreoptic endoscopy in Japan (SHIRAKABE et coll 1966 SHIRAKABE 1972 KAWAI & TANAKA 1974) is mainly due to improvement of the double contrast method Similar experiences are reported in Europe and North America (EIKEN 1958 GELFAND & HACHIYA 1969 KREEL et coll 1973 HEDEMAN & MATHIASEN 1974 LAUFER 1975) As a routine procedure the technique seems to have been adopted only in a few centres The main arguments against its wider acceptance have been that the technique is too cumbersome and unpleasant for the patient and the films are difficult to evaluate It has also been said that double contrast examinations were of value only for detection of malignancy neglecting its greater accuracy in diagnosis of atrophic and errosive gastritis healed ulcers intestinal metaplasia (AOYAMA 1971) and giant hypertrophic gastritis (KREEL et coll 1973 KOIKE et coll 1975) Barium sulphate preparations of low viscosity and high density are nowadays available but the introduction of gas or air into the stomach has not been satisfactorily solved

The present technique using a conventional drinking straw with a side hole is simple and effective With this technique more than 40 per cent of the stomach is outlined by double contrast in over 65 per cent of the patients The examination takes 15 to 20 minutes for the experienced examiner It may be applied to all patients including recumbent and immobile as well as those with severe vertebral deformities Metoclopramide increases gastric and intestinal motility without increasing gastric

secretion (KREEL 1975 SELLINK 1976) Thus residual gastric juice is emptied which results in improved adhesion of the barium suspension It is also effective after vago tomy (BANKE 1969) The compound was found to be particularly useful after con ventional barium meal in the 15 patients with possible abnormality as well as patients with food retention in the stomach After intramuscular injection of 10 to 20 mg the examination could be repeated after 1 to 2 hours without any disadvantage (Fig 6)

The use of hypotonic agents permits detailed analysis of all areas of the stomach unaffected by peristalsis They delay the passage of the barium suspension into the third part of the duodenum and proximal jejunum which would otherwise obscure parts of the stomach They also make it possible to perform tubeless hypotonic double contrast duodenography in all patients (Fig 4) Buscopan and Glucagon have the advantage of having relatively few side effects

Other techniques for double contrast examination of the stomach such as the use of effervescent powders or granules and acidulous waters are published They in crease the amount of gastric juice and usually produce air bubbles requiring use of silicone antifoaming agents Air bubble formation was rarely observed when barium suspension was sipped simultaneously with air. Except nasogastric intubation only the present method ensures appropriate dosage of air for satisfactory distension of the stomach The present technique is definitely more practical and effective than alternative procedures and is now routinely used in this department in all patients above 40 years and in younger where gastric malignancy is suggested

Acknowledgements

The authors are grateful to Mrs Poula Hansen senior radiography nurse for her enthu siasm and helpful suggestions

SUMMARY

Double contrast examination of the stomach has a greater accuracy than conventional barium meal especially in the diagnosis of minor gastric lesions The use of a common drinking straw with a side hole to introduce air simultaneously with the barium suspension after gastric emptying with metoclopramide and using short acting hypotonic agents like Buscopan and Glucagon provides a practical and effective simplified technique for double contrast examination of the oesophagus stomach and duodenum

ZUSAMMENFASSUNG

Die Doppelkontrastuntersuchung des Magens hat eine grossere Genauigkeit als die konventionelle Bariummahlzeit besonders bei der Diagnose von kleineren Lasionen des Magens Die Anwendung eines gewohnlichen Trinkhalms mit einer Seitenoffnung um gleich zeitig Luft mit der Bariumsuspension nach Entleerung des Magens mit Metoclopramide und der Verwendung kurzzeitig wirkender hypotonischer Substanzen wie Buscopan und Glucagon einzufuhren bieten eine praktisch und effektiv vereinfachte Technik zur Doppel kontrastuntersuchung des Ösophagus des Magens und des Duodenums

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METHOD FOR COMPARING FILMS AND PROCESSING PROCEDURES IN PHOTOFLUOROGRAPHY

K. HANSEN and F WELDE

Stepped wedges used in radiography usually have steps giving a constant change or a known change in log transmitted exposure (SEEMAN & ROTH 1960) The transmitted exposure of the steps in the present stepped wedge (Al) corresponds to the transmitted exposure of defined parts of the chest from the parts with the highest to those with the lowest accumulation It is thus possible directly to control film density corresponding to defined parts of the chest for different films processing procedures and exposures

Construction of the stepped wedge

Defined parts of the chest The photographic density in selected areas of photofluorographic films of the chest are compared with steps in a stepped wedge The defined areas are easily recognized from one film to another (Fig 1) The geometric dimensions refer to 70 mm film size

1 The mean photographic density D_m determined from an area of 10 mm × 20 mm imaging the middle of the lung is used as a reference
2 This area is also divided in 50 smaller areas (2 mm × 2 mm) The mean density of the 5 densest of these areas is denoted D_1 the mean density of the 5 least dense is

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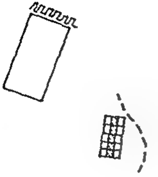


Fig 1

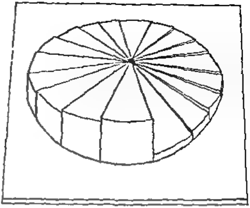


Fig 2

Fig 1 Defined areas in lungs for measurements of photographic density in photofluorogram

Fig 2 The Al rosette (the stepped wedge) The steps increase 3 mm Al from 9 to 60 mm The Al rosette can be rotated in the radiation beam to give the same phototimer response as the average man It is mounted on an Al plate to reduce stray light

3 In the least dense part of the films 10 areas (2 mm × 2 mm) were defined 5 areas are located where aorta and the heart are seen to overlap on the films and 5 where the lung and the heart overlap The mean densities are denoted D_3 and D_4 respectively

Determination of the steps The height of the steps in a stepped wedge were made to correspond in transmitted exposure and resulting photographic density to the defined parts of the chest by the following measurements

1 The mean exposure time $\bar{t}_{ph}$ (for male subjects) was determined using photo timer
2 An Al rosette (Fig 2) close to the fluorescent screen was adjusted to give the $\bar{t}_{ph}$ and was exposed immediately after the exposure of male subjects with $\bar{t}_{ph}$
3 The transmitted exposure (both primary and secondary radiation included) was measured by taping LiF TL dosemeters behind the steps in the Al rosette
4 The films of 20 male subjects exposed with $\bar{t}_{ph}$ were selected Of these 9 films of subjects close to the normal ratio of body height to body weight were selected and used as films of the normal chest The densities in the defined areas were measured in these films The mean values were denoted $\bar{D}_m$ $\bar{D}_1$ $\bar{D}_2$ $\bar{D}_3$ and $\bar{D}_4$ respectively
5 The density in the films behind the steps of the Al rosette was measured Mean values were used A photofluorographic unit with 115 kV 2 mm Al total filter 70 mm mirror optics camera and 90 cm focus screen distance was used for the measurements

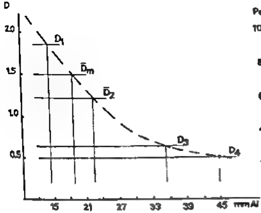


Fig 3

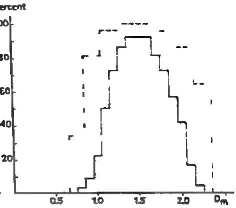


Fig 4

Fig. 3 The density behind the steps in the Al rosette as a function of Al thickness $\bar{D}_m$ $\bar{D}_1$ $\bar{D}_2$, $\bar{D}_3$, $\bar{D}$ plotted in

Fig 4 Evaluation of image quality as a function of D_m whole line = good image quality broken line = acceptable image quality

The densities behind the steps in the Al rosette are given as a function of Al thickness in the steps in Fig 3 The defined densities $\bar{D}_m$ $\bar{D}_1$ $\bar{D}$ $\bar{D}_3$ and $\bar{D}_4$ are plotted in It is evident that the density produced by 14 mm Al corresponds to $\bar{D}_1$ 19 mm Al to $\bar{D}_m$ 22 5 mm Al to $\bar{D}$ 35 mm Al to $\bar{D}_3$ and the density produced by 45 mm Al corresponds to $\bar{D}_4$

The Al rosette is used as stepped wedge with the following approximated thicknesses 15 mm ($\bar{D}_1$) 18 mm ($\bar{D}_m$) 24 mm ($\bar{D}$) 36 mm ($\bar{D}_3$) and 45 mm ($\bar{D}_4$)

Quality criteria of films and processing

Evaluation of films A material of 85 photofluorographic films (of male subjects) of different reference densities D_m was evaluated by 16 radiologists All accepted films with D_m between 1 3 and 1 7 (Fig 4)

Fig 5 shows measured contrasts in the 85 photofluorographic films as a function of D_m D_1–D is the maximum contrast in the part of the film with the highest photographic density (i e that part of the lung with the lowest accumulation of the radiation) D_1–D_3 is the maximum contrast in the whole lung It is evident that both contrasts reach flat maxima D_1–D has its maximum at the lower end of the interval for D_m accepted by all and D_1–D_3 reaches its maximum at the upper end of this interval

Photographic density and contrast parameters The following parameters that are equivalent to parameters used in connection with film characteristic curves were used

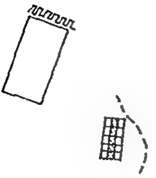


Fig 1

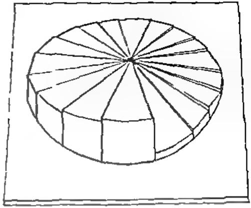


Fig 2

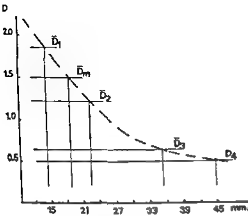
Fig 1 Defined areas in lungs for measurements of photographic density in photofluorogram

Fig 2 The Al rosette (the stepped wedge) The steps increase 3 mm Al from 9 to 60 mm The Al-rosette can be rotated in the radiation beam to give the same phototimer response as the average man. It is mounted on an Al plate to reduce stray light

3 In the least dense part of the films 10 areas (2 mm × 2 mm) were defined 5 areas are located where aorta and the heart are seen to overlap on the films and 5 where the lung and the heart overlap The mean densities are denoted D_3 and D_4 respectively

Determination of the steps The height of the steps in a stepped wedge were made to correspond in transmitted exposure and resulting photographic density to the defined parts of the chest by the following measurements

1 The mean exposure time $\bar{t}_{ph}$ (for male subjects) was determined using phototimer
2 An Al rosette (Fig 2) close to the fluorescent screen was adjusted to give the $\bar{t}_{ph}$ and was exposed immediately after the exposure of male subjects with t_{ph}
3 The transmitted exposure (both primary and secondary radiation included) was measured by taping LiF TL dosemeters behind the steps in the Al rosette
4 The films of 20 male subjects exposed with $\bar{t}_{ph}$ were selected Of these 9 films of subjects close to the normal ratio of body height to body weight were selected and used as films of the normal chest The densities in the defined areas were measured in these films The mean values were denoted $\bar{D}_m$ $\bar{D}_1$ $\bar{D}_2$ $\bar{D}_3$ and $\bar{D}_4$ respectively
5 The density in the films behind the steps of the Al rosette was measured Mean values were used A photofluorographic unit with 115 kV 2 mm Al total filter 70 mm mirror optics camera and 90 cm focus screen distance was used for the measurements



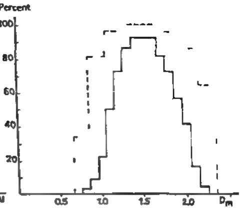


Fig. 3

Fig 4

Fig 3 The density behind the steps in the Al rosette as a function of Al thickness $\bar{D}_m$ $\bar{D}$ $\bar{D}_2$ $\bar{D}$ $\bar{D}$ plotted in

Fig 4 Evaluation of image quality as a function of D_m whole line = good image quality broken line = acceptable image quality

The densities behind the steps in the Al rosette are given as a function of Al thickness in the steps in Fig 3 The defined densities $\bar{D}_m$ $\bar{D}_1$ $\bar{D}$ $\bar{D}_3$ and $\bar{D}_4$ are plotted in It is evident that the density produced by 14 mm Al corresponds to $\bar{D}_1$ 19 mm Al to $\bar{D}_m$ 22 5 mm Al to $\bar{D}$ 35 mm Al to $\bar{D}_3$ and the density produced by 45 mm Al corresponds to $\bar{D}_4$

The Al rosette is used as stepped wedge with the following approximated thicknesses 15 mm ($\bar{D}_1$) 18 mm ($\bar{D}_m$) 24 mm ($\bar{D}$) 36 mm ($\bar{D}_3$) and 45 mm ($\bar{D}_4$)

Quality criteria of films and processing

Evaluation of films A material of 85 photofluorographic films (of male subjects) of different reference densities D_m was evaluated by 16 radiologists All accepted films with D_m between 1 3 and 1 7 (Fig 4)

Fig 5 shows measured contrasts in the 85 photofluorographic films as a function of D_m D_1–D_2 is the maximum contrast in the part of the film with the highest photographic density (i e that part of the lung with the lowest accumulation of the radiation) D_1–D_3 is the maximum contrast in the whole lung It is evident that both contrasts reach flat maxima D_1–D has its maximum at the lower end of the interval for D_m accepted by all and D_1–D_3 reaches its maximum at the upper end of this interval

Photographic density and contrast parameters The following parameters that are equivalent to parameters used in connection with film characteristic curves were used

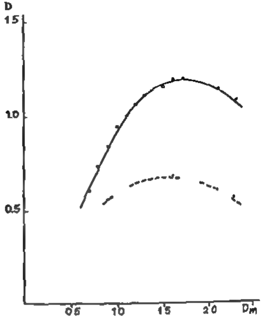


Fig 5 Measured contrast as a function of D_m whole line $= D_1 - D_3$ broken line $= D_1 - D_2$

a) $\overline{D}_m$ the reference density

b) $\gamma_1 = \dfrac{\overline{D}_1 - \overline{D}_2}{\lg E_1 - \lg E}$ the maximum γ in the photographically densest part of the lung E_1 and E_2 are the transmitted exposures for the steps in the Al rosette corresponding to $\overline{D}_1$ and $\overline{D}_2$ respectively

c) $\gamma_2 = \dfrac{\overline{D}_1 - \overline{D}_3}{\lg E_1 - \lg E_3}$ the maximum γ in the whole lung E_1 and E_3 are the transmitted exposures for the steps in the Al rosette corresponding to D_1 and D_3 respectively

d) $\gamma_3 = \dfrac{\overline{D}_3 - \overline{D}_4}{\lg E_3 - \lg E_4}$ the maximum γ in the mediastinum E_3 and E_4 are the transmitted exposures for the steps in the Al rosette corresponding to $\overline{D}_3$ and $\overline{D}_4$ respectively

e) $\overline{D}_4 - D_f$ the difference in density between the photographically least dense parts of the chest $\overline{D}_4$ and the fog density D_f

The acceptable intervals for the parameters are as follows

1) $1\ 3 < \overline{D}_m < 1\ 7$ as determined by the evaluation of the radiologists

2) $\gamma_1 \approx$ maximum as determined by the evaluation and referred density measurements in the test material

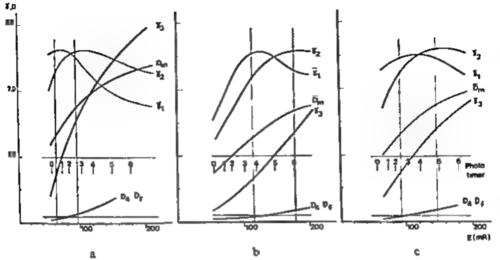


Fig. 6 Contrast-exposure diagram. a) Film 1 Developed alone b) Film 2 Developed alone c) Film 1 Developed with normal image production

3) $\gamma_1 > \gamma_2$ — the evaluation and referred density measurements in the test material showed that also D_1–D_3 and hence $\bar{\gamma}_2$ should be close to a maximum γ_1 and γ do not have maxima for the same exposure A reasonable compromise is to demand that $\gamma_1 > \gamma$

4) $\gamma_3 \geqslant 1\ 0$ — It is difficult to set a sharp limit for the acceptable interval of γ_3 $\gamma_3 > 1\ 0$ is a demand that usually agrees well with the demands referred

5) $\bar{D}_4 - F \geqslant 0\ 1$ — It is difficult to set a sharp limit for the acceptable interval of $\bar{D}_4 - D_f$ $\bar{D}_4 - D_f > 0\ 1$ is a demand that agrees well with the demands referred

It should be pointed out that the acceptable intervals for the defined parameters might be chosen otherwise without changing the principles of the method

The results are obtained by using a film with base density 0 30 For parameters (a) and (c) this must be taken into consideration when evaluating films with other base densities

Practical application of the method

When comparing films or processing procedures the rosette is exposed for each phototimer setting or fixed exposure time the exposure is measured simultaneously

in air 25 cm from the screen and in the middle of the beam using a Victoreen 666 instrument diagnostic chamber. The density behind the steps in the Al rosette is measured. Contrast and density are plotted versus exposure. The contrast exposure diagrams demonstrate how contrast and gradient γ vary with exposure behind the defined parts of the chest.

Fig. 6 exemplifies what may be read out of the diagrams. Two commonly used films and two processing procedures are compared.

The vertical lines give acceptable interval for $\overline{D}_m$. Film 1 has about the same maximum γ_1 and γ_2 as film 2, and about the same γ_3 in the useful interval. Film 1 is more sensitive than film 2. However, the latter film has a wider useful range of exposure. Different processing does not much change the maximum γ, but changes sensitivity and useful range of exposure (Fig. 6 a–c). However, the conclusions drawn from these examples are not representative for all photofluorographic films and processing procedures.

Conclusion

The method has proved to be useful for comparing measurements of films and processing procedures and for control and standardization of the exposure. The spread in the parameters for different films and film deliveries may be controlled by repeated tests. The method is used as part of a system for continuous control of mass chest surveys. From the point of view of radiation hygiene the method gives a good review of the relationship between image quality and patient doses. The present results are strictly valid only for the radiation quality used (115 kV, 2 mm Al). A stepped wedge made of a material more equivalent to biologic tissue after the principles outlined would be useful. Minor modifications are necessary for the application of the method elsewhere in diagnostic radiology.

SUMMARY

A method for comparing measurements of films and processing procedures is described. A stepped wedge is developed on basis of density measurements in defined areas of chest photofluorographic films. Quality criteria for films and processing procedures are established by systematization of film evaluation. Minor modifications of the method are necessary for application elsewhere in diagnostic radiology.

ZUSAMMENFASSUNG

Eine Methode zu Vergleichsmessungen von Filmen und Entwicklungsverfahren wird beschrieben. Es wurde ein abgestufter Keil auf der Basis von Dichtemessungen bestimmter Gebiete von photofluorographischen Filmen des Thorax entwickelt. Qualitätskriterien der Filme und der Entwicklungsverfahren wurden durch Systematisierung der Filmauswertung aufgestellt. Es sind geringere Abänderungen der Methode zur beliebigen Anwendung des Verfahrens innerhalb der diagnostischen Radiologie notwendig.

RESUME

Les auteurs decrivent une methode pour comparer les mesures de densite des films et les techniques de developpement Ils ont mis au point un coin à gradins basé sur les mesures de densite dans des regions definies de films de radiophotographies du thorax Ils ont établi les critères de qualité pour les films et les techniques de développement par la systématisation de l appreciation des films De petites modifications de cette méthode sont nécessaires pour l appliquer dans tous les domaines du radiodiagnostic

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REDUCTION OF ABSORBED DOSE IN RADIOGRAPHY OF THE BREAST

Experience with a new screen film combination

I ANDERSSON L ANDRÉN M NILSSON and C PETTERSSON

An increased frequency of carcinoma of the breast among patients repeatedly examined with fluoroscopy during treatment with artificial pneumothorax because of pulmonary tuberculosis was reported by MACKENZIE (1965) This finding was corroborated by MYRDEN & HILTZ (1969) in a more extensive analysis of the same group of patients

DELARUE et coll (1975) on the other hand were unable to find any difference in frequency of mammary carcinoma in patients treated and untreated with pneumo thorax However certain fundamental differences exist between the series of MAC KENZIE and that of DELARUE et coll viz in the former the patients were examined in the prone position the breast thus facing the roentgen tube while those in the latter were examined in the supine position In addition in most cases no filtration was used in the series of MACKENZIE DELARUE et coll calculated that the 6 patients in their treated series who developed carcinoma had received an average absorbed dose of 17 rad The corresponding absorbed dose delivered to the breast had the patients been examined prone was estimated to be 308 rad The average dose received by the whole group is not evident from the data presented

According to METTLER et coll (1969) the incidence of carcinoma of the breast was increased in a group of patients treated with roentgen radiation because of post

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Table

Mean absorbed doses with and without intensifying screens

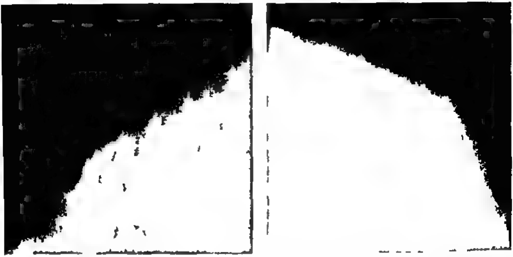
Film or screen film combination	Absorbed dose			
	Range		Mean value	
	mGy	mrad	mGy	mrad
Mamoray T3	0-29	1000-2900	17	1700
Lo-dose	1 4-4	140-400	2	00
MR 50—Mamoray RP 3	0 6-2	60-.00	1	100

partum mastitis Among the survivors of the atomic bombing of Hiroshima and Nagasaki the frequency of mammary carcinoma was also found to be increased (WANEBO et coll 1968) It has been calculated from their data that the incidence of mammary carcinoma is doubled when the breast is exposed to an absorbed dose of 20 rad (TAMPLIN & GOFMAN 1970) which is within the range of a single examination of the breast with industrial film

Recently radiography of the breast as a screening procedure was critically discussed by BAILAR (1976) with emphasis on the radiation hazards There is a remarkable lack of information concerning the effects of the radiation used in mammary radiography but there is reason to believe that this examination carries a certain risk of inducing carcinoma It is essential to find methods permitting reduction of the absorbed dose without significant loss of quality of the films PRICE & BUTLER (1970) seem to have been among the first to use intensifying screens packed in vacuum cassettes They used Medichrome film and reported good results Later Du Pont introduced the Lo dose system consisting of a single emulsion film and a calcium tungstate screen packed in a vacuum cassette (OSTRUM et coll 1973) Intensifying screens markedly reduce the dose Data on the absorbed doses required for industrial film and screen film combinations have been published by ASBURY & BARKER (1975)

Screen films and industrial films were compared at this department but the images obtained with Medichrome film were not satisfactory as they lacked in detail while those obtained with the Lo-dose system were quite acceptable

Recently a new system from Agfa Gevaert was tried It is based on lantanoxybromide screens (MR 50) and a special double coated film (Mamoray RP 3) packed in a vacuum cassette The investigation comprised 1 733 patients referred because of symptoms from the breasts Three views of each breast frontal lateral and axillary were taken In the first 135 patients the screen film combination was used for the frontal and lateral projections and industrial film (Mamoray T3 Agfa Gevaert) for the axillary projection In the following 1 598 patients the industrial film was omitted routinely and all 3 views were obtained on the MR 50 – RP 3 system Thus both systems were not used routinely in the same projection to avoid unnecessary increase of the absorbed dose In both series only breasts considered suitable for



The MR 50 RP 3 system was placed under the left part of the breast and the Lo dose system under the right part Both were exposed simultaneously to demonstrate the difference in sensitivity between the two systems

comparison i e breasts with overt carcinoma or possibly malignant lesions as well as breasts difficult to evaluate on the primary films were examined in one or more views with both systems (299 breasts) The roentgen equipment (Diagnost M Philips) has a molybdenum anode and a photo timer exposure data 31 kV 170 mA The absorbed doses were measured with thermoluminescent dosemeters (LiF teflon thickness 0 4 mm diameter 12 7 mm) One dosemeter was attached to the lower surface of the compression plate and one to the film vacuum cassette Thus the entrance and exit absorbed doses were measured From these data the mean absorbed dose was calculated A formula (derived from the integral dose concept) for calculating the mean absorbed dose is given by

$$D_{mean} = (D_{en} - D_{ex})/\log(D_{en}/D_{ex})$$

where D_{en} is the absorbed dose at the entrance side of the breast and D_{ex} the absorbed dose at the exit point This formula is an approximation However comparison of results of mean dose calculations based on depth dose measurements in water phantoms of adequate thicknesses show little divergence

It is evident from the Table that the dose required by the Agfa Gevaert system for a given density of the film is only half of that necessary for the Du Pont Lo dose system (Figure) Compared with Mamoray T3 the new system permits a 90 to 95 per cent reduction of the exposure The mean absorbed dose per exposure was about 1 mGy (100 mrad) which is in the same range as that for an ordinary chest examination Compared with industrial film and xeroradiography the dose reduction is substantial and with all probability the risk of inducing malignancy is small probably negligible

The use of screens inevitably implies some loss of resolution This is compensated to som extent by increased contrast Small calcifications were often better defined on industrial film but were sometimes easier to recognize on the Mamoray RP 3 film owing to its better contrast The impression was that significant lesions demonstrable on industrial film are invariably recognized on usage of the screen film system No apparent difference in quality was found between the views obtained with the Du Pont and Agfa Gevaert systems The latter system is definitely not inferior to the former

Conclusion The difference in quality between industrial film and the new screen film combination from Agfa Gevaert is small but the dose reduction so remarkable as to make the use of a good screen system mandatory Compared with the Du Pont Lo-dose system the Agfa Gevaert system reduces the absorbed dose still more

SUMMARY

The mean absorbed dose in radiography of the breast with industrial film (Mamoray T3 Agfa Gevaert) the Lo-dose system (Du Pont) and a new screen film combination (MR 50-Mamoray RP 3 Agfa Gevaert) was determined The mean values were 17 2 and 1 mGy respectively Thus the absorbed dose was considerably reduced by using the screen film combination This is of utmost importance as the potential risk of inducing malignancy is remarkably reduced probably negligible

ZUSAMMENFASSUNG

Die durchschnittliche absorbierte Dosis bei der Untersuchung der Brust wurde mit einem industriell n Film (Mamoray T3 Agfa Gevaert) dem Lo-Dose System (Du Pont) und einer neuen Schirm Film Kombination (MR 50-Mamoray RP 3 Agfa Gevaert) bestimmt Mittel werte betrugen 17 2 und 1 mGy Die absorbierte Dosis war somit bei der Schirm Film Kombination wesentlich reduziert Das ist von grosser Bedeutung, da das potentielle Risiko Malignität zu induzieren wesentlich reduziert ist und wahrscheinlich zu vernachlässigen ist

RESUMÉ

La dose moyene absorbée dans radiographie du sein avec le film industriel (Mamoray T3 Agfa Gevaert) le systeme Lo-dose (Du Pont) et une nouvelle combinaison ecran film (MR 50-Mamoray RP 3 Agfa Gevaert) a ete mesuree Les valeurs moyennes ont ete 17 2 et 1 mGy respectivement Ainsi la dose absorbée est considerablement reduite par l emploi de la combinaison écran film Ceci est de la plus grande importance car le risque potentiel d induire une tumeur maligne e t remarquablement reduit probablement negligeable

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ANTIBACTERIAL EFFECTS OF METRIZOATE AND METRIZAMIDE ON BACTERIAL GROWTH IN VITRO

J G JOHANSEN and O G CLAUSEN

Radiography of patients with urinary tract infections is performed using various contrast media The question arises whether the presence of these media in the urinary tract influences the accuracy of urine cultures obtained after such examinations In vitro experiments indicated that in certain concentrations water soluble iodinated contrast media may have an inhibitory action on bacterial growth (SVOBODA & JEZKOVÁ 1960 SACHSE 1969 NARINS & CHASE 1971 KUHNS et coll 1972) Whether Isopaque (Na Mg Ca metrizoate) or Amipaque (metrizamide) exert any antibacterial effects is not known This fact motivated the investigation which is now reported

Material and Methods

Bacteriostatic effects Five urinary pathogens originally isolated from patients were used *Pseudomonas aeruginosa Escherichia coli Proteus vulgaris Staphylococcus aureus* and *Streptococcus faecalis* Isopaque and Amipaque were tested in concentrations of 100 mg I/ml and 260 mg I/ml The following dilutions of Isopaque 100 mg I/ml in sterile destilled water were also tested 1/10 1/100 1/1 000 and 1/10 000

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Table

Bacteriostatic effects of Isopaque and Amipaque Diameter of wells filled with contrast medium = 10 mm Numbers without parentheses – Diameters in mm of wells and growth free ones Numbers in parentheses – Diameters in mm of wells and ones with relative growth inhibition 0 = No growth inhibition

Test bacteria	Isopaque				Amipaque			
	100 mg I/ml pH 7 0		260 mg I/ml pH 7 3		100 mg I/ml pH 7 1		260 mg I/ml pH 6 9	
	PDM agar	Sensitivity blood agar	PDM agar	Sensitivity blood agar	PDM agar	Sensitivity blood agar	PDM agar	Sensitivity blood agar
Ps aeruginosa	0	0	0	0 (14)	0	0	0	0
E coli	0	0	0	0 (15)	0	0	11 (12)	11 (14)
P vulgaris	0	0 (15)	16 (27)	16	0	0	11	0
S aureus	0	0	0 (11)	0	0	0	0	0 (traces)
Str faecalis	0	0	0 (traces)	0	0	0	0	0

A method implying diffusion in solid media of two types was used PDM agar (Paper disc method antibiotic sensitivity medium) and blood agar for sensitivity testing Aqueous dilutions of 20 h cultures (37 C) of the bacteria in nutrient broth were poured over the plates The whole agar surface was covered by the fluid which was subsequently removed with a pipette and the plates were dried at 37 C Holes were then made in the inoculated solid media with a sterile cork bore with a diameter of 10 mm and solutions of the contrast media were placed in the wells with pasteur pipettes The plates were then incubated for 20 h at 37 C before measurement of the diameters of growth inhibition zones (CLAUSEN 1962)

Results Isopaque 260 mg I/ml had a slight bacteriostatic effect on *P vulgaris* Both contrast media in the same concentration had only a negligible effect on some of the bacteria (Table) Low concentrations were ineffective except for a negligible effect of Isopaque 100 mg I/ml on growth of *P vulgaris* on sensitivity blood agar medium

Bactericidal effects Isopaque and Amipaque in concentrations of 100 mg I/ml and 260 mg I/ml were tested on *Ps aeruginosa E coli* and *S aureus* To 1 ml contrast medium 0 1 ml of 20 h cultures (37 C) of the bacteria in nutrient broth was applied and the mixture was well shaken Test temperature was about 22 C Inoculated solution was then transferred with one platinum loop full (4 mm ID) to 10 ml growth medium dithionite thioglycollate broth (CLAUSEN et coll 1973) at the following intervals 5 10 15 and 30 min 1 2 24 and 48 hours The control tubes were incubated at 37 (CLAUSEN 1973)

Results Uninhibited growth occurred in all the test tubes after 24 hours of incubation

Discussion

It is uncertain how contrast media may inhibit bacterial growth but the effect is probably due to their iodine content Although the iodine atoms are firmly bound in the molecules traces of inorganic iodide due to contamination may be detected in bottled contrast media (PILEGGI et coll 1962 LANG et coll 1974 COEL et coll 1975) Slight deiodination occurs when contrast media are exposed to roentgen radiation (SCHUSSLER 1962) or sunlight (LANG et coll 1974) There is evidence that a slight deiodination may take place in vivo (TALNER et coll 1973)

Increase of osmolality of a culture medium to as high as 1 053 has no effect on the growth of *E coli* (NARINS & CHASE 1971) Amipaque is non dissociable in solution and has consequently only half of the osmolality of Isopaque and other monomer ionic contrast media in equal iodine concentration In reality the osmolality of Amipaque has been measured to be even less (HOLTERMANN 1973) The present results display slightly stronger effect by Isopaque on *P vulgaris* but otherwise no significant difference between the two contrast media was evident The slight differences in pH (in the range of 6 9 to 7 3) are not considered to be of any importance

At the department of radiology Isopaque Cysto (100 mg I/ml) is used in cystography and Isopaque 45 % (260 mg I/ml) in retrograde pyelography Urography is performed by intravenous injection of 30 ml Isopaque 60 % (350 mg I/ml) containing 10 5 g of iodine In 6 hours 86 per cent of Isopaque is excreted in unchanged form in the urine (DAWSON 1968) Because of osmotic diuresis the iodine concentration in the urine must be much less than 100 mg I/ml Maximum concentration of iodine in urinary samples taken in intervals after intravenous injection of sodium metrizoate containing 15 g of iodine has been measured to be only 50 to 60 mg % (BENNESS 1965)

The results indicate that Isopaque or Amipaque in the concentrations used does not influence the reliability of urine cultures obtained subsequent to radiography of the urinary tract

SUMMARY

Urinary pathogens were exposed in vitro to Isopaque and Amipaque in concentrations of 100 mg I/ml and 260 mg I/ml Both contrast media in the higher concentration had a slight or negligible bacteriostatic effect on some of the test bacteria No bactericidal effect was detected Consequently radiography of the urinary tract with these two media in the concentrations mentioned does not interfere with the culturing of bacteria from urine samples

ZUSAMMENFASSUNG

Pathogene Erreger vom Harn wurden in vitro in Berührung mit Isopaque und Amipaque in Konzentrationen von 100 mg I/ml und 260 mg I/ml gebracht Beide Kontrastmittel hatten bei der höheren Konzentration einen leichten oder unbedeutenden bakteriostatischen Effekt auf einige der Testbakterien Es konnte keine bakterizide Wirkung festgestellt werden Demzufolge bedeutet die Röntgenuntersuchung der Harnwege mit diesen zwei Kontrastmitteln in der erwähnten Konzentration kein Hindernis in Verbindung mit dem Kultivieren von Bakterien von Urinproben

RESUME

Des germes pathogenes urinaires ont ete exposes in vitro à l Isopaque et a l Amipaque a des concentrations de 100 mg I/ml et 260 mg I/ml Ces deux moyens de contraste ont a la concentration la plus elevee un effet bacteriostatique léger ou negligeable sur certaines des bactéries-tests Les auteurs n ont pas décelé d effet bactéricide Par conséquent la radiographie des voies urinaires avec ces deux moyens de contraste aux concentrations mentionnees n influe pas sur la culture des bacténes à partir de prelévements d urines

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SUPERIOR OPHTHALMIC VEIN AT COMPUTED TOMOGRAPHY

J BRISMAR GUDRUN BRISMAR and K R DAVIS

The superior ophthalmic vein is the main intraorbital vein and is connected by abundant collaterals directly or indirectly with all other intraorbital veins It is always filled at orbital phlebography in normal cases provided an adequate phlebographic technique is used (BRISMAR 1974) and is also usually demonstrable following selective injection into the maxillary artery Occasionally the superior ophthalmic vein is filled following selective injection into the internal carotid artery the diagnostic implications of such a finding have been the subject of recent reports by HACKER & PORRERO (1969) and TORNOW & PISCOL (1971)

The superior ophthalmic vein is formed behind the pulley of the superior oblique muscle by the union of tributaries from the supraorbital and angular veins Initially it courses posteriorly but soon turns laterally to enter the muscular cone crossing under the superior rectus muscle (anterior segment) It appears again on the lateral side of this muscle and then runs postero medially following the lateral border of the superior rectus muscle (middle segment) The vein then descends to leave the orbit through the superior orbital fissure (posterior segment) and empties into the cavernous sinus

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From Harvard Medical School and the Department of Radiology (Director Prof J M Taveras) Massachusetts General Hospital and the Department of Ophthalmology (Director Prof C H Dohlman) Massachusetts Eye and Ear Infirmary Boston Massachusetts 02114 USA (J B now at Department of Neuroradiology University of Lund S 221 85 Lund Sweden) Submitted for publication 19 July 1976

RESUME

Des germes pathogènes urinaires ont été exposés in vitro à l Isopaque et à l Amipaque à des concentrations de 100 mg I/ml et 260 mg I/ml Ces deux moyens de contraste ont a la concentration la plus elevée un effet bacteriostatique léger ou négligeable sur certaines des bacteries tests Les auteurs n ont pas décele d effet bactéricide Par conséquent la radio graphie des voies urinaires avec ces deux moyens de contraste aux concentrations men tionnées n influe pas sur la culture des bacteries à partir de prélévements d urines

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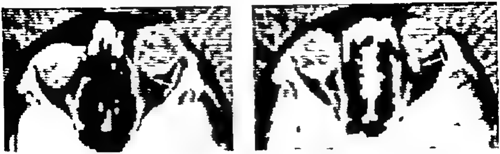

a b

c

Fig 2 Case 8 Right sided carotid-cavernous fistula Consecutive sections without contrast medium enhancement a) Optic nerve (→) b) Superior ophthalmic vein (↦) c) Superior rectus and levator palpebrae muscles (↦)

vein was identified only on the enhanced scan in one of these 3 patients while in the remaining two it was also observed on the native scan

A carotid cavernous fistula was present in 2 patients (Figs 1 2) and drained through the superior ophthalmic vein identified on the scan These were the only 2 patients in the series with an arteriovenous fistula The remaining 8 patients in whom the vein was identified (Fig 3) had a variety of disorders (Table) the majority of which are not likely to influence the appearance of the orbital vein Only the anterior segment of the vein was evident in most of the cases (Figs 1 2) but in one case the vein could be followed through the entire orbit (Fig 3) The diameter of the vein (measured and corrected for reduction in size from the Polaroid films) was 3 to 4 mm in 9 of the cases but was 7 mm in one of the cases with a fistula (Fig 1)

Discussion

Each section in computed tomography is comprised of a matrix of picture elements (pixels) of specific size A structure will be demonstrated if it significantly changes the attenuation value of one or several pixels Not only the difference in attenuation between the structure and surrounding tissue but also the volume the structure occupies within each pixel is therefore of importance

The difference in attenuation number between the pixels containing the superior

a b

Fig 3 Case 4 Left-sided Grave s disease Consecutive sections following infusion of contrast medium Anterior and middle segments of superior ophthalmic vein (↦) in the section above that of the optic nerve (→)

ophthalmic vein and the pixels of surrounding tissue may vary considerably depending on whether the vein is included in pixels also containing structures with a comparatively high attenuation such as the superior rectus muscle (and perhaps also the orbital roof) or in pixels containing mostly retrobulbar low attenuating fat The attenuation difference is larger in the latter case and thus the probability of identifying the vein is higher The use of overlapping sections by increasing the possibility

Table

Ten patients in which the superior ophthalmic vein was identified at computed tomography Ant = anterior segment Middle = middle segment — = the vein not identified (—) = superior ophthalmic vein not identified but uppermost part of orbit not adequately examined 0 = not performed

Case No	Sex age	Part of vein demonstrated				Final clinical diagnosis
		Native scan		Post infusion scan		
		Right	Left	Right	Left	
1	F 53	—	—	Ant	Ant	Right sided orbital pseudotumor
2	F 70	(—)	(—)	—	Ant	Temporal arteritis papillitis sarcoma of Kaposi
3	F 45	(—)	(—)	—	Ant	Cerebral cerebellar metastases
4	F 57	(—)	(—)	Ant and middle	—	Left-sided Grave s disease
5	M 27	(—)	(—)	(—)	Ant	Right-sided ethmoiditis
6	M 63	(—)	(—)	Ant	—	Right-sided orbital pseudotumor
7	M 54	—	Ant dilated	—	Ant dilated	Left-sided carotid-cavernous fistula
8	F 81	Ant	—	0	0	Right-sided carotid-cavernous fistula
9	F 49	—	Ant	—	Ant	Periodic migrainous neuralgia
10	M 53	0	0	—	Ant	Tuberous sclerosis left optic atrophy

of demonstrating the vein more optimally in relation to the surrounding structures therefore increases the chances for its recognition Intravascular administration of constrast medium is another means for increasing the attenuation difference between the vein and the surrounding tissue

Narrow collimation (reduced height of the pixel) centered round the vein will cause the vein to occupy a larger fraction of the pixel and thus increase the prospects of its identification The dimensions of the superior ophthalmic vein may vary considerably between normal subjects the maximum diameter of the superior ophthalmic vein at orbital phlebography being between 0 8 and 4 8 mm when no venous compression is applied (BRISMAR) The injection pressure in these subjects probably distended the vein but these figures nonetheless give some indication of the normal range of the dimensions of the vein The orbital veins dilate in association with arteriovenous fistulas draining through the orbit More frequent identification of the vein is therefore to be expected in association with such fistulas since the probability of demonstrating the vein at computed tomography is also related to its size This was the situation in the present material where the vein was identified in both of the two cases with fistula included but in only 8 out of the 78 cases without a fistula

Demonstration of the superior ophthalmic vein at computed tomography (particularly if it appears dilated) with the current technique should thus raise the question if an arteriovenous malformation draining through the orbit is present

This work was carried out while J B was on leave from the Department of Radiology (Section on Neuroradiology) and G B from the Department of Ophthalmology University Hospital S 221 85 Lund Sweden

SUMMARY

The superior ophthalmic vein may occasionally be observed at computed tomography of the orbit This finding does not in itself imply pathology but should nevertheless raise the question as to whether an arteriovenous fistula is present particularly if the vein appears dilated

ZUSAMMENFASSUNG

Die Vena ophthalmica superior kann gelegentlich bei der Komputer Tomographie der Orbita beobachtet werden Diese Befunde haben an und fur sich keine pathologische Bedeutung bei Dilatation der Vene sollte jedoch an das Vorliegen einer arteriovenosen Fistel gedacht werden

RESUME

La veine ophtalmique supérieure peut parfois etre observée dans la tomographie avec ordinateur de l orbite Cette constatation n a pas en elle meme de signification pathologique mais doit cependant faire penser à la possibilité d une fistule arterioveineuse specialement si la veine parait dilatee

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VASCULAR OCCLUSION WITH A FERROMAGNETIC PARTICLE SUSPENSION

An experimental investigation in rabbits

U ALBRECHTSSON G Å HANSSON and T OLIN

Surgical treatment of oesophageal varices arterial aneurysms and arteriovenous shunts is often difficult Occlusion by embolization or sclerosing injection to induce thrombosis has therefore been tried (CRAFOORD & FRENCKNER 1939 LUESSENHOP et coll 1962) Magnetically controlled material containing iron has been tested for this purpose (MEYERS et coll 1963 ALKSNE et coll 1966 FINGERHUT & ALKSNE 1966 RAND & MOSSO 1973) and in order to increase knowledge of this method the following experiments were designed

Material and Methods

Twenty two rabbits (weighing between 2 0 and 4 5 kg) were used General anaesthesia was obtained by intravenous injection of pentobarbiton- sodium (Mebumal natrium) In 16 rabbits an iron particle suspension was injected through a scalp vein cannula in one of the ear veins whilst a magnetic field was applied to the homolateral superficial vein in the neck Two different magnets were used a large horseshoe magnet (Eclipse 8 cm in diameter and 5 cm long with 9 cm long poles) and a so called pot magnet (Eclipse 3 5 cm in diameter 3 cm long) The magnetic field was applied for periods up to 100 minutes after the injection In 3 rabbits the azygos vein was catheterized from the right jugular vein and injected while the magnetic field was

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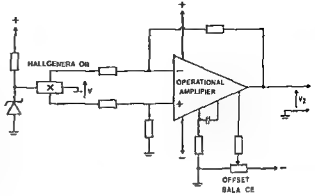

Fig. 1. Hall generator with amplifier. The Hall generator obtains its bias current from the Zener diode and the Hall voltage (v_1) is amplified ten times by the integrated operation amplifier. This solution has the advantage of a high output voltage with low impedance (v_2) that can be connected to a universal voltmeter as well as an easy offset balancing of the whole system including the Hall generator.

applied either against the animal's back by the horseshoe magnet or in the oesophagus by a catheter (OD/ID = 2.75/1.8 mm) containing four small cylindric rod magnets (diameter 1.6 mm, Deutsche Edelstahlwerke, Dortmund, Germany). In 3 animals the arterial system was injected after catheterization from the femoral artery. In these experiments an outer magnetic field was applied by the horseshoe magnet around the neck and the iron particle suspension injected through the catheter. The cannulas and catheters were rinsed by injection of physiologic saline containing 500 IU/ml Heparin. In 11 rabbits an antifibrinolytic agent (Cyclocapron 1 mg tranexamic acid) was administered intravenously after the injection of the iron particle suspension.

The iron particles (carbonyl iron, Kebo, Sweden) had an average diameter of about 4 μm and a maximum diameter of 10 μm. Their sedimentation rate was determined in the following solutions: 30 % and 50 % glucose (ACO, Sweden), Rheomacrodex with 10 % glucose (Pharmacia, Sweden), Isopaque 350, Isopaque 440, Isopaque Coronar and Isopaque Cerebral (metrizoic acid, Nyegaard, Norway). The lowest sedimentation rate was obtained with Isopaque Coronar which therefore was used in the animal experiments. The iron suspension (0.5 g iron and 2 ml Isopaque Coronar) was injected under fluoroscopy in amounts of 0.5 to 1.0 ml. Angiography of the vessels of interest was performed before and immediately after the injection of the iron particle suspension and again repeated during several months. 4 animals were followed for 12 months after the iron injection. Chest films were taken in an attempt to reveal embolization. At autopsy the occluded vessels and the thrombus were removed for microscopy.

To calibrate the magnets used, the following technical measurements were made. The field intensity of the magnets was measured by making use of the so called Hall effect, i.e. by passing an electrical current through a body (nowadays usually a semiconductor of InAs or InSb) in a magnetic field and measuring the electric current which appears at right angles to the applied current. A Hall generator of this type (Siemens SV 110 II) with an amplifier was used for the present measurements (Fig. 1).

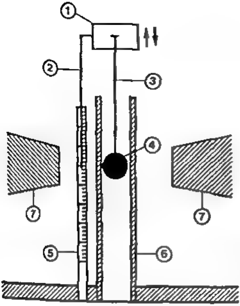

Fig 2 The apparatus for measuring the magnetic force exerted on an iron ball The strain gauge the reference stick and the string with the iron ball are movable in the vertical plane which makes it possible directly to read the magnetic force exerted on the iron ball and relate this to the distance between the ball and the centre of the magnet (see also Figs 16 17 18 and 19) Numerals denote the strain gauge (1) reference stick (2) string (3) iron ball (4) scale (5) brass tube (6) and poles of the magnet (7)

The apparatus was first calibrated against an electro magnet in which the coils had a known number of turns and the current conducted was known Thereafter the intensity of the magnetic fields of the experimental electro magnet and permanent magnets was measured

The force exerted on an iron particle in a magnetic field depends not only on the field but also on the particle itself Therefore the force exerted by the magnets upon an iron ball 2 0 or 4 0 mm in diameter was measured directly in a simple apparatus (Fig 2) with the ball contained within a brass tube and connected to a strain gauge (Swema S 64 180) which could be moved up and down along a scale The measurements were performed in the midline of the magnetic field first in one direction and then in the opposite direction

Results

Injection of iron particle suspension into the ear vein was performed in 16 animals In 7 of these the horseshoe magnet was placed with the magnetic field across the superficial jugular vein with one pole on either side of it In these rabbits the iron particles were well trapped by the magnetic field and localized thrombus developed in the vein Collateral circulation appeared especially to the contralateral superficial jugular vein through extra and intracranial veins at the base of the skull Some small muscular and subcutaneous collaterals developed ipsilaterally and small collaterals sometimes occurred al o ı the spinal region If the magnet was applied for 100 min the thrombus adh red ∖ ll to the wall of the vessel and did not embolize later on (Figs 3 4) Sixty m n ı cation of the magnet field was sometimes insuf

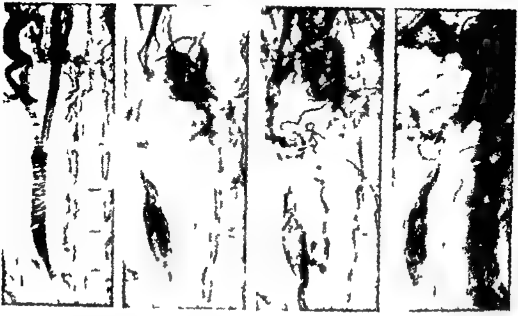

Fig 3 a) Phlebography Fresh thrombus with the iron particles oriented in the magnetic field The magnetic field of the large permanent horseshoe magnet has been applied across the jugular vein for 100 min b) Direct radiography of the neck 21 weeks later Swollen and organized thrombus c) Phlebography a p projection Occlusion of the jugular vein but by passing collaterals d) Lateral projection

ficient to moor the thrombus safely to the wall In 9 of the 16 rabbits the horseshoe magnet was placed on one side of the vein with the magnetic field along the vessel (Fig 5) The trapping of the iron particles was less efficient and the thrombus did not always completely occlude the vessel Fixation of the thrombus to the wall of the vessel was in some cases not quite sufficient even after 100 min application of the magnetic field (Fig 6) as some embolization to the lung was revealed at control angiography and chest radiography one to fifteen weeks after the injection of the iron suspension

In the 3 rabbits which received injection of the iron particle suspension through a catheter in the azygos vein thrombus formation occurred in the small veins draining into the azygos vein after application of the horseshoe magnet field The small rod magnets in the oesophagus were not strong enough to trap the iron particles When injected into the arterial system the particles were not caught by the magnetic field and no large localized thrombus was formed

The localized thrombus did not change macroscopically during the first week of control Thereafter the thrombus became swollen and organized with resultant separation of the iron particles Organization was completed after 2 to 3 months and thereafter the thrombus remained unchanged for the rest of the observation

Fig. 4 a) Fresh thrombus in the jugular vein moored by the large horseshoe magnet applied across the vessel b) Phlebography Occlusion of the vein but collaterals to the other jugular vein at the skull base c) Direct radiography 15 weeks later The thrombus is swollen and organized d) Phlebography The jugular vein is still occluded e) Phlebography 30 weeks after creation of the thrombus The thrombus is unchanged as compared to c and d f) One year after creation of the thrombus The thrombus is unchanged (4 times enlargement)

period which in some cases lasted up to 12 months Microscopy showed a thrombus containing large amounts of iron The vessels were irregular and sometimes ectatic The walls of the vessels [illegible] thickened with inflammatory cells Most prominent though were the [illegible] giant cells and resorption cells containing iron

Fig 5 a) Phlebography of the external jugular vein The poles of the permanent horseshoe magnet ■ applied along the vessel b) 15 weeks after a thrombus was created in the jugular vein The iron thrombus is situated in an ectatic pouch of the vein Blood flow ■ unaffected

pigment When iron material had embolized to the lungs similar abnormalities were seen in the pulmonary vessels The parenchyma of the lungs per ■ was without abnormality Thrombus formation was not significantly different in the 11 rabbits which received tranexamic acid

Technical view points

The Hall generator was first calibrated against an electro magnet Thereafter the intensity of the magnetic field B(T) of the other electro magnet (Fig 7) and of the permanent horseshoe magnet (Fig 10) and the pot magnet (Fig 13) was measured in the midline as a function of the distance from the centre of each of the magnets The derivative dB/dx(T/m) of this function was also calculated (Figs 8 11 14) as was the product of the intensity of the magnetic field and its derivative ■ dB dx(T²/m Fig 9) From these values the magnetic force (N) was calculated (Figs 12 15) The force exerted by a magnet on an iron particle is due to the fact that the particle is magnetized when introduced into the magnetic field A measure of this magnetization is the permeability μ which is close to unity for non magnetic material and very high for ferromagnetic materials such as iron The magnetic force acting upon an iron particle may theoretically be calculated as acting upon a surface or upon ■ volume In this case volume force is to be preferred According to the laws of electricity (HALLÉN 1968 p 163)

$$\bar{f} = \text{grad}\ ^1\ (M\ B)$$

$\bar{f}$ = force per unit volume M = magnetization of the body B = intensity of the magnetic field The total force $\bar{F}$ is obtained by integrating $\bar{f}$ for the entire volume This

a b

Fig 6 15 weeks after a thrombus was created in the jugular vein Due to too short application of the horseshoe magnet the iron thrombus has embolized to the lung a) A p projection b) Lateral projection

formula cannot be applied directly since it implies that M and B inside the body are known The intensity of the field in the absence of iron cannot be used since the field is deformed by the presence of iron This deformity of the field can be calculated for a sphere in a homogeneous field

$$M = \frac{3}{\mu_0} B_0$$

where B_0 is the intensity of the magnetic field in the absence of the sphere and M and B represent the values inside the sphere To establish whether this expression may be used for practical calculations even in a non homogeneous field the following estimation of the force was made

$$\bar{f} = 9/2 \text{ grad } (M_0 B_0)$$

or approximately

$$\bar{f} = \frac{9}{2\mu_0} \text{ grad } B_0$$

since $M \approx B/\mu_0$ and $B \approx 3B_0$

The total force is then obtained by integration over the volume of the sphere Considering the small dimension of the iron particles this integration can be approximated by multiplying with the volume of the sphere

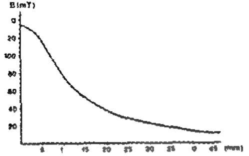

Fig 7

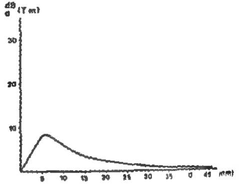

Fig 8

Fig 7 The magnet field (B) versus the distance from the centre of the electro magnet (x mm) The field was measured with the Hall generator along the midline of the electro magnet

Fig 8 The derivative of the magnetic field (dB/dx) versus the distance from the centre of the electro magnet (x mm) The derivative was geometrically constructed point by point from Fig 7

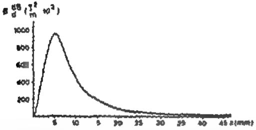

Fig 9

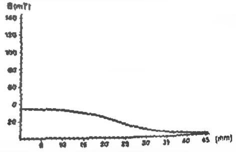

Fig 10

Fig 9 The product of the magnetic field (B) and its derivative (dB/dx) versus the distance (x mm) from the centre of the electro magnet This diagram was used to calculate the adjustment factor (K) The factor is defined as the ratio between the measured and the theoretically calculated maximum force

Fig 10 The magnetic field (B) versus the distance (x mm) from the centre of the Eclipse horseshoe magnet The measurement was performed with the Hall generator in the same way as in Fig 7

The magnetic force exerted by the electro magnet upon the iron balls 2 0 and 4 0 mm in diameter is illustrated in Figs 16 and 17 The measurements were performed in the midline of the magnetic field, first in one direction and then in the opposite direction The difference in force is due to the friction between the ball and the wall of the brass cylinder The friction force was 1 7 per cent for the large ball and 1 2 per cent for the small one and thus negligible Theoretically the total force will be

$$F = \frac{9}{\mu_0} B \frac{dB}{dx} \frac{4}{3}\pi r^3$$

where r (m) is the radius of the ball and F (N) is directed towards the centre of the

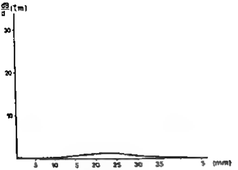

Fig 11

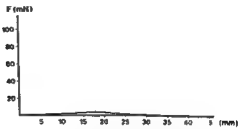

Fig 12

Fig. 11 The derivative of the magnetic field (dB/dx) of the Eclipse horseshoe magnet versus the distance from the centre of the magnet (x mm) This diagram was geometrically constructed from Fig 10

Fig 12 The estimated magnetic force (F) exerted on the 4 0 mm iron ball versus the distance (x mm) from the centre of the Eclipse horseshoe magnet The force was estimated as K 3 10 B dB dx πr^3 where K was found to be 0 62 upon comparison with the directly measured force (see Fig 18)

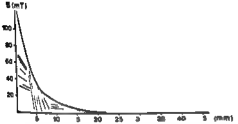

Fig 13

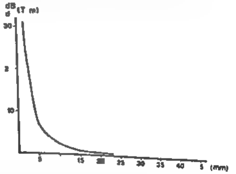

Fig 14

Fig 13 The magnetic field (B) versus the distance (x mm) from the centre of the Eclipse pot magnet The measurements were performed with the Hall generator in a similar way to those in Fig 7 The original construction of the derivative is shown

Fig 14 The derivative of the magnetic field (dB/dx) of the Eclipse pot magnet versus the distance from the centre of the magnet (x mm) This diagram was geometrically constructed from Fig 13

magnetic field The maximum force exerted by the electro magnet on the 4 0 mm ball will be 230 mN using this formula and the measurements obtained with the Hall generator The calculated value exceeds the directly measured value by a factor of 2 6 The corresponding value for the small ball is 29 mN and the factor 2 1 On comparison of the product of the field strength (B) and its derivative (dB/dx) on the one hand (Fig 9) and the force directly exerted on the 4 0 mm ball (Fig 17) on the other it is apparent that the curve based on directly measured force is much flatter The same tendency although less marked is evident for the small ball (Fig 16) These findings suggest that the deformation of the magnetic field caused by the ball

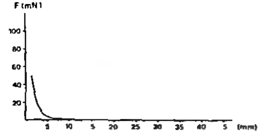

Fig 15

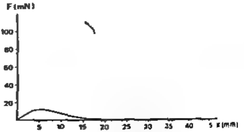

Fig 16

Fig 15 The estimated magnetic force (F) exerted on the 2 0 mm iron ball versus the distance (x mm) from the centre of the Eclipse pot magnet The force was estimated as K 3 10^7 B dB dx πr^3 where K was found to be 0 5 upon comparison with the directly measured force (see Fig 19)

Fig 16 The force (F) exerted on the 2 0 mm iron ball in the field of an electro magnet versus the distance (x mm) from the centre of the magnet The force was measured with the apparatus described in Fig 2 and the result should be compared with the product of the field from the electro magnet and its derivate (see Fig. 9)

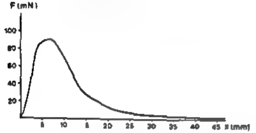

Fig 17

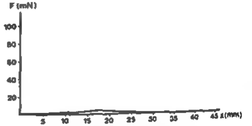

Fig 18

Fig 17 The force (F) exerted on the 4 0 mm iron ball in the field of an electro magnet versus the distance (x mm) from the centre of the magnet The force was measured with the apparatus described in Fig 2 and the result should be compared with the product of the field from the electro magnet and its derivate (see Fig 9)

Fig 18 The force (F) exerted on the 4 0 mm iron ball in the field of the Eclipse horseshoe magnet versus the distance (x mm) from the centre of the magnet The force was measured with the apparatus described in Fig 2 and the result should be compared with the estimated force (see Fig 12)

increases with the size of the ball In the presence of the ball the magnetic field around it seems to be homogeneous Thus the derivative of the magnetic field will diminish and also the force acting upon the ball This effect should be enhanced where the derivative of the magnetic field is large i e close to the maximum of the magnetic field The theoretical formula

$$\bar{F} = \frac{9}{2\mu_0} \text{ grad } B_0 \ V,$$

simplified for a sphere to

$$\bar{F} = \frac{3 \times 10^7}{2} \text{ grad } B_0 \ \pi r^3$$

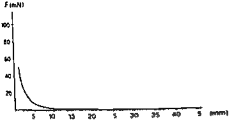

Fig 19 The force (F) exerted on the 2 0 mm iron ball in the field of the Eclipse pot magnet versus the distance (x mm) from the centre of the magnet The force was measured in a way similar to that shown in Fig 2 and the result should be compared with the estimated force (see Fig 15)

can be further simplified to

$$F = 3 \times 10^7 \, B_0 \, \frac{dB_1}{dx} \, \pi r^3$$

where F is directed towards the centre of the magnetic field This expression has to be adjusted by a factor K which depends upon the size of the ball and the shape of the magnetic field At diameters of 2 0 and 4 0 mm respectively K was 0 48 and 0 38 When a very small particle is used it is probably close to unity

Direct measurement of the magnetic force was performed with the large horseshoe magnet (Fig 18) The 4 0 mm ball was used and the curve was compared with the calculated curve based on the measurement of the magnetic field (Fig 12) The two curves coincided well The adjustment factor K was found to be 0 62 which is higher than for the electro magnet previously used probably because the permanent magnet has a more homogeneous field When similar measurements (Fig 19) and calculations (Fig 15) were made with the pot magnet and the 2 0 mm ball the adjustment factor was 0 5 Again the measured and the calculated curves agreed well The measurements revealed that the force acting on the ball is large only within a short range of the pot magnet It is very small at a distance of 4 mm

Discussion

The animal experiments confirmed the results of ALKSNE et coll (1966) and those of RAND & MOSSO (1973) that it is possible to create an occluding thrombus in a vessel by injecting an iron particle suspension and manipulating the particles with a magnet However there are certain prerequisites for success During the development of an iron thrombus within a blood vessel there is a very complex interplay between magnetic and haemodynamic forces If the linear velocity of the blood is high as it is in the common carotid artery the iron particles will not be captured by the trap In the superficial jugular vein volume flow is of the same magnitude as in the carotid artery but the linear velocity is low and the iron particles can therefore be trapped by the magnetic field ALKSNE et coll could arrest iron particles in the femoral

arteries of dogs using cylindrical Alnico 5 bar magnets 6 mm in diameter and 75 mm in length applied directly against the adventitia of the vessel

The orientation of the magnetic field is also of importance If the magnetic field of the horseshoe magnet was applied parallel to the vessel an iron thrombus developed along its nearest wall When such a thrombus has grown large enough it will act as a magnetic screen behind which it is increasingly easy for iron particles to pass the magnet

When the horseshoe magnet was applied across the vein trapping was very efficient and a solid thrombus formed When the pot magnet was applied at right angles to the blood vessel the result was about the same as when the horseshoe magnet was positioned along the vessel

The small rod magnets in the oesophagus were at a distance of about 3 cm from the azygos vein The magnetic force was therefore too weak to capture the iron particles

Post injection treatment with an antifibrinolytic agent did not stabilize the thrombus further It may be that the raw iron surface hinders lysis of the thrombus To moor the thrombus firmly to the wall of the vessel the horseshoe magnet had to be kept in position for 100 minutes During this long period the iron particles may to some extent be drawn into the intima of the vessel promoting fixation of the thrombus ALKSNE et coll in experiment with dogs suggested an exposure time of one hour for aneurysmal pouches and four days for the femoral artery MEYERS et coll (1963) using a strong magnet (5 000 gausses) around the leg of a dog discovered that iron particles in the femoral artery to some extent were pulled through the vessel wall

The technical measurements revealed that it is possible to predict the force exerted upon an iron particle It is proportional to the product of the field and its derivative which can be measured relatively simply with a Hall generator Such measurements and calculations enable comparison of different magnets

The linear velocity of the blood flow is often quite high in situations where the method might be of value for example through an arteriovenous shunt Temporary arrest of the flow with a balloon catheter might facilitate the development of a localized solid thrombus The flow velocity in oesophageal varices is usually not very high but it is difficult to obtain a strong magnetic field in this area with a catheter contained system of rod magnets in the oesophagus Further animal experiments are therefore recommended before the clinical application of magnetically controlled iron thrombi

SUMMARY

Magnetically controlled iron thrombosis has been attempted in rabbits A horseshoe magnet across the jugular vein could arrest injected iron particles in the blood stream so that a well localized solid thrombus developed The connection between the strength and orientation of the magnetic field and the force developed on the iron particles was also investigated

ZUSAMMENFASSUNG

Eine magnetisch kontrollierte Eisen Thrombose wurde bei Kaninchen versucht Ein Hufeisenmagnet uber die Vena jugularis konnte injizierte Eisenpartikel im Blutstrom so fixieren dass sich gut lokalisierte solide Thromben entwickelten Der Zusammenhang zwischen der Grosse und der Orientierung des magnetischen Feldes und der auf die Eisenpartikeln entwickelten Kraft wurde ebenfalls untersucht

RESUMÉ

Les auteurs ont essayé de faire sur des lapins une thrombose au moyen de particules de fer dirigees par un aimant Un aimant en fer a cheval place en travers de la veine jugulaire peut arreter les particules de fer injectées dans le courant sanguin permettant la formation d un thrombus solide bien localisé Les auteurs ont aussi étudie les rapports entre l intensité et l orientation du champ magnétique et la force développee sur les particules de fer

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Book review

ARTERIOVENÖSE FISTELN DILATIERENDE ARTERIOPATHIEN (ANEURYSMEN) Edited by J F Vollmar and P Nobbe 176 pages with 82 figures and 35 tables Georg Thieme Verlag Stuttgart 1976 Price DM 39 80

The book contains contributions to a meeting in 1974 at Ulm (Deutsche Gesellschaft fur Angiologie) and consists of two parts In the first part arteriovenous fistulas in the extremities and in the second aneurysms of the aorta and of arteries in the extremities are discussed The authors originate mainly from German speaking areas of Europe

The first part begins with a chapter on the normal short circuits in the human circulation followed by one on the arteriovenous fistulas in the general circulation Diagnostic methods are discussed in four chapters In addition to ordinary clinical signs such as the presence of a murmur and Nicoladoni Branham s sign particular attention is paid to methods such as plethysmography thermodilution ultrasound and a method utilizing tracer microspheres In the method last mentioned the tracer microspheres are injected into the artery of an extremity The microspheres are 5 to 50 μm in diameter and most of them are trapped in the normal capillaries In the presence of an arteriovenous shunt however they slip through and are then captured in the lungs Analysis of the amount of nuclide in the extremity and in the lungs is made by using a suitable detector In the presence of a normal capillary bed the leakage to the lungs will be only a few per cent When an arteriovenous fistula is present a higher percentage will appear in the lungs and this will be proportional to the blood flow through the shunt The term Shuntvolumen (%) which is used for this percentage is not well chosen since that parameter is not a volume but a percentage of the flow The method seems promising and has been applied successfully in the United States and Denmark as well as in Vienna The roentgen diagnosis of arteriovenous shunts is briefly described by Wenz and Beduhn Much emphasis is laid on vascular abnormalities combined with hypertrophy of an extremity The syndromes of Weber and Klippel Trenaunay are thoroughly described and discussed by Vollmar The surgical therapy of acquired and congenital arteriovenous shunts is also closely debated

The second part of the book deals with aneurysms of the aorta and the arteries of the extremities Their distribution and frequency are shortly discussed The diagnostic method especially recommended is angiography In the opinion of the reviewer more emphasis should be laid on ultrasound scanning for the diagnosis of abdominal aneurysm With regard to ultrasound there is an interesting chapter dealing with flow analyses in aneurysms with a pulsed ultrasound Doppler flowmeter Central aneurysms are discussed by DeBakey from Houston USA The surgery of peripheral aneurysms including popliteal ones is discussed in two chapters

The book is the result of a symposium which means that there are some reiterations The discussions after each of the two sections of the book bridge the gaps between the different contributions The work is especially recommended to vascular surgeons and ought also to prove of interest to orthopaedic surgeons internists cardiologists and radiologists

Tord Olin

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR: PROF. P. VIRTAMA), UNIVERSITY CENTRAL HOSPITAL, SF 05 0 TURKU, FINLAND

INTRAVENOUS BOLUS OF ^{125}I LABELED MEGLUMINE DIATRIZOATE

Early extravascular distribution

P. B. DEAN and M. KORMANO

The greater part of an intravenously injected dose of diatrizoate rapidly leaves the circulation for the extracellular space, from which it gradually returns to the circulation and is excreted by the kidneys (BENNESS 1973, CATTELL et coll. 1967, JUNKMANN 1959 and MCCHESNEY & HOPPE 1957). In this respect diatrizoate behaves in a manner similar to other small organic molecules such as inulin and hippuran (MORRIS et coll. 1965). Although intracellular distribution of diatrizoate has been suggested in an in vitro perfusion experiment (LÖHR et coll. 1974), it is likely that this accounts for only an insignificant proportion of the total diatrizoate space.

Assuming that little, if any, diatrizoate is located in the intracellular space, then determination of the equilibrated extravascular space of diatrizoate will give, in effect, the extracellular fluid space. Although diatrizoate is presumably distributed throughout the extracellular fluid space after long term infusion (LAGEMANN 1975, 1976), no data are available in the literature dealing with distribution immediately after an intravenous bolus of diatrizoate. The present investigation was carried out to measure the early changes in the extravascular distribution of diatrizoate within individual tissues following an intravenous bolus injection.

Submitted for publication 10 September 1976.

Materials and Methods

Twenty six male rats of the Sprague Dawley strain under intraperitoneal pentabarbitone anesthesia were each given a rapid injection into the right femoral vein After an elapsed time interval of 5 10 20 40 or 120 s (4 rats each) or of 300 s (6 rats) the lower extremities and genitalia were severed with a guillotine and immediately immersed in liquid nitrogen for several min then stored at −20 C until dissected over dry ice Blood samples were taken by open cardiac puncture immediately after severing the rat

A mixture of ^{125}I labeled meglumine diatrizoate (100 mg/ml specific activity 0 5 mCi/ml free I$^-$<0 1 % Schering AG Berlin) diluted with an equal volume of meglumine diatrizoate (100 mg/ml) and ^{131}I labeled human serum albumin (20 mg/ml specific activity 0 63 mCi/ml The Radiochemical Centre Amersham) was injected 0 1 ml/rat (body weight range 290 to 400 g avg 360 g) The meglumine diatrizoate dose averaged 24 8 mg/kg (range 21 5 to 29 9 mg/kg) and the osmolality of the mixture was 243 m osmol/kg

Tissue samples were dissected from thirteen sites on the frozen left leg and both testes including (1) red muscle (anterior tibial) (2) white muscle (biceps femoris) (3) bone cortex (tibia) (4) bone marrow (tibia) (5) fat (popliteal fossa) (6) skin (lateral calf—superficial layers) (7) subcutaneous tissue (lateral calf) and (8) testis (after removal of tunica) Samples were not taken from the right leg to avoid a possible contamination from the injection site The samples were placed in preweighed test tubes weighed immediately and 2 ml concentrated nitric acid added before counting with an automatic scintillation well counter (LKB Wallac Turku) with windows set for ^{125}I and ^{131}I Each run was controlled with an ^{125}I standard (^{129}I) and the results were corrected for sample decay and Compton scatter The activity of each sample was determined in terms of disintegrations/mg/min and standardized to an injection of 10 μCi of each isotope per rat with the rat weight adjusted to 400 g (actual amounts injected ranged from 15 0 to 21 8 μCi ^{125}I and 8 6 to 10 0 μCi ^{131}I per rat)

Calculations Plasma activity was calculated as the blood activity divided by a hematocrit of 50 per cent (FARRIS & GRIFFITH 1949) as diatrizoate does not penetrate the red corpuscle (PHELPS et coll 1973) The total volume of distribution of diatrizoate or diatrizoate space was calculated as the ratio of the dose divided by the plasma concentration (GILLETTE 1973) expressed as a percentage Similarly the percentage distribution volume in the individual tissues or the tissue space was calculated as the ratio of tissue to plasma activity (MANERY & BALE 1941) expressed as a percentage

Albumin tissue space initially represents the plasma volume as labeled albumin injected intravenously into a rat remains virtually entirely within the vessels during at least the first 3 min (EVERETT et coll 1956) Subtracting the albumin space from the diatrizoate space produces the extravascular space of diatrizoate

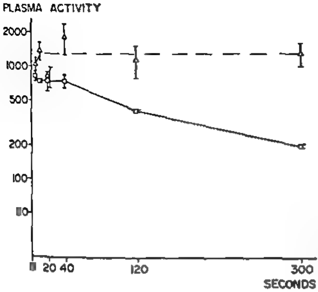

Fig 1 Plasma activity (disintegrations/mg/min) of labeled albumin (△) and diatrizoate (□) in cardiac blood Each point represents the mean ±SEM

The extravascular fraction of tissue diatrizoate can be calculated as the ratio of the extravascular total diatrizoate spaces expressed as a percentage This ratio added to the ratio of the intravascular total diatrizoate spaces equals unity or 100 per cent

Results

Plasma activity Diatrizoate and albumin activity in the plasma of mixed cardiac blood are presented in Fig 1 Plasma albumin levels remained (with some fluctuations presumably due to experimental variation) at approximately the same level throughout the period measured whereas diatrizoate activity which had already fallen to almost half the albumin activity at 10 s began to fall still further after 40 s The diatrizoate space is in an inverse relationship to the plasma diatrizoate concentration Part of the rapid decrease between 40 and 300 s is due to renal excretion

Tissue activity Albumin activity remained nearly constant in all tissues from 40 to 300 s In red and white muscle there was a marked fall in albumin activity over the first 40 s in the remaining tissues the level was nearly constant throughout with a slight initial rise in skin and subcutaneous tissue Diatrizoate activity (the topmost curve in Fig 2) rose substantially in skin and subcutaneous tissue was nearly constant or rose slightly in testis and fat and fell in white and red muscle bone and bone marrow

Albumin and diatrizoate spaces Albumin space representing the relative vascular volume of the tissues followed nearly the same pattern described for albumin activity

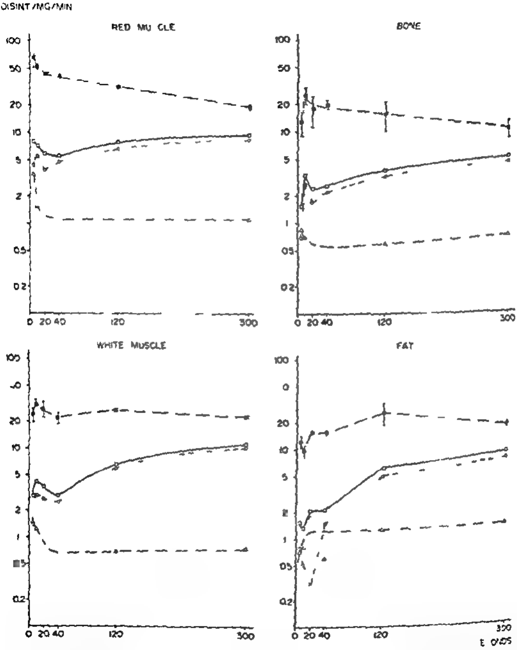

Fig 2 Activity of labeled diatrizoate in disintegrations mg/min in each tissue is shown as the topmost curve in each graph (■) as mean SEM The three lower curves in each graph represent total distribution volume of diatrizoate ( ) extravascular part of the distribution volume of diatrizoate (○) and albumin distribution volume ( ) all three as percentages of total tissue volume

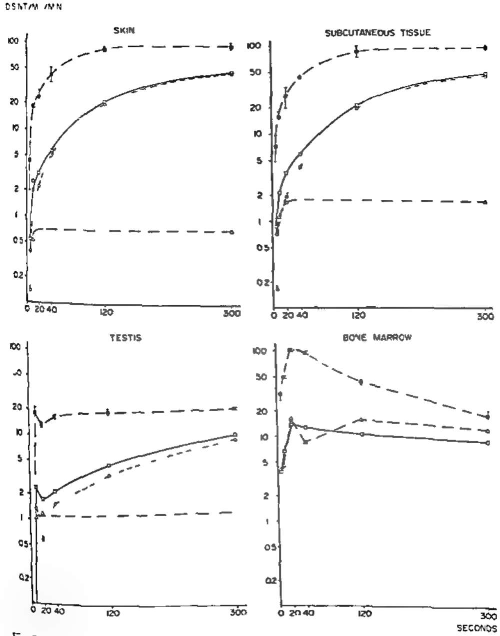

Fig 2. (For legend see opposit page)

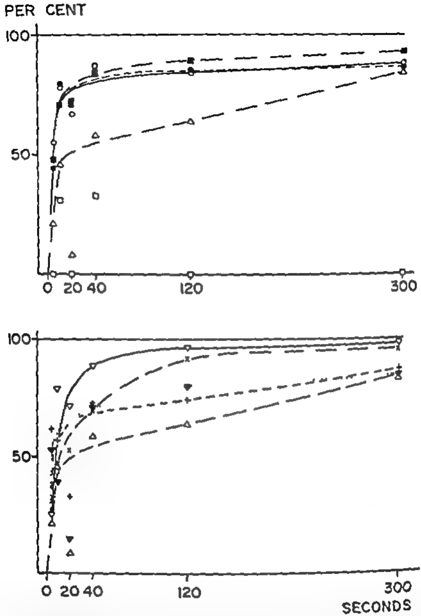

Fig 3 Percentage of extravascular/total diatrizoate in individual tissues and average values for the entire rat The amount below each curve represents the percentage of diatrizoate in the extravascular space The percentage of diatrizoate remaining in the vessels is shown by the space between each curve and the 100 per cent line ■ white muscle ○ red muscle ● bone □ bone marrow ▽ skin × subcutaneous tissue ▼ fat + testis △ entire rat

(Fig 2) The diatrizoate space of every tissue examined except bone marrow was immediately greater than the albumin space and increased with time apparently still increasing at 5 min These values do not require correction for renal excretion as do those of the whole body diatrizoate space

Extravascular diatrizoate fraction These values calculated for the individual tissues appear in Fig 3 The extravascular diatrizoate fraction averaged for the entire rat is shown in both graphs for reference with the amount excreted by the kidneys included as part of the extravascular fraction The area above each curve represents the intravascular diatrizoate fraction Diatrizoate is seen to distribute primarily within the extravascular space by 20 to 40 s in the whole rat and in most of the tissues examined with the exception of bone matrow in which there appeared to be no definite extravascular distribution In all tissues except bone marrow the extravascular fraction of diatrizoate appeared to be still increasing at 5 min

Discussion

Diffusion of a contrast medium to the extravascular space occurs when the plasma concentration exceeds the concentration in extracellular fluid immediately adjacent to the capillary wall With a given dose of contrast medium the flux of the medium to the extravascular space of a given tissue is a function of (1) blood flow (2) capillary permeability (3) rate of diffusion through the extravascular tissue space (and occurrence of concentration gradients within this space) (4) volume of the extravascular space (5) protein binding of the contrast medium within the plasma and extravascular space

In the nearly steady state or pseudoequilibrium situation the amount of extravascular uptake should depend only upon (4) and (5) in addition to the plasma concentration However in the non equilibrium situation after bolus injection (1) (2) and (3) may also modify the amount of contrast medium reaching the extravascular space Equilibrium levels may not be reached before the fall in plasma concentration resulting from urinary excretion

Diatrizoate rapidly reached the extravascular space after bolus intravenous injection as expected for a small (molecular weight = 613) water soluble anion Capillary walls in non neural tissues seemed to cause little barrier to the initial distribution which was very rapid and approximately half the injected dose was extravascular after one passage through the body (Fig 3) The total extravascular fraction continued to increase with renal excretion accounting for an increasing share of the extravascular diatrizoate The tissues measured (with the exception of bone marrow) continued to expand their apparent diatrizoate spaces even with falling tissue concentrations in muscle fat and bone

Diffusion through the free interstitial connective tissue space is very rapid and unlikely to cause any significant diffusion barrier in comparison with transcapillary passage (LAURENT 1972) Binding of diatrizoate to albumin is unlikely to markedly influence distribution (LANG & LASSER 1967 LANGECKER et coll 1954) On the other hand cellular membranes and intercellular tight junctions may slow down or even prevent diffusion of the contrast medium into and from the transcellular fluid (EDELMAN et coll 1952) much of which is contained by skin and excretory glandular

tissue It is possible to estimate the relative contributions of the above factors in the individual tissues from the shape of the temporal distribution curves

Red muscle and bone appear to have the most rapid rates of intravascular—extravascular equilibration of diatrizoate of the tissues measured as tissue diatrizoate concentration peaked at 5 and 10 s respectively and levels most closely followed the plasma concentration Muscle in particular appeared to act in a storage function releasing diatrizoate to the circulation to be redistributed to other tissues as evidenced by a rapid initial rate of fall in muscle diatrizoate concentration exceeding that in plasma After 40 s the rate of fall in blood concentration exceeded that in muscle concentration producing a slight increase in the apparent diatrizoate space The pattern for bone was nearly identical although the absolute values were about half those of red muscle

Compared with red muscle the lower initial concentration of diatrizoate and its lower rate of fall in white muscle may be explained by the intermittent opening and closing of the capillaries in white muscle (HUDLICKA 1973) which exposes additional extravascular space to diatrizoate the capillaries in red muscle being continuously open

The uptake in adipose tissue indicates an increase of total concentration up to 2 min and a further increase in distribution volume even after 2 min It seems unlikely that the diatrizoate ion is able to enter the fat cells to a significant amount The relatively small diatrizoate space of fat was shown to equilibrate substantially more slowly than that of muscle and bone

The extended slow rise in testis diatrizoate concentration cannot be explained on the basis of slow circulation and hence of delayed transcapillary passage alone (SETCHELL 1970) Compartmentation of the testis into strictly separate tissue spaces offers a reasonable explanation of this late uptake despite the falling plasma diatrizoate concentration Outside the blood vessels the interstitial tissue up to the tight junctions formed by the Sertoli cells of the seminiferous tubules forms a relatively freely accessible extracellular fluid compartment An intratubular compartment exists beyond the so-called blood testis barrier which is less accessible to a variety of substances (SETCHELL 1970) OKUMURA et coll (1975) found drug transport across the blood testis barrier to closely resemble transport across the blood brain barrier It was assumed that the initial rapid uptake of diatrizoate is to the interstitial tissue compartment and the subsequent rise represents slow uptake by the luminal fluid of the seminiferous tubules resulting in an initially small distribution volume which shows a slow increase LAGERMANN (1975 1976) also observed a relatively low uptake of diatrizoate by the testis

The largest distribution volumes were measured in the skin and subcutaneous tissues The more superficial skin had less than half the albumin space of subcutaneous tissue and an extravascular vascular diatrizoate ratio reaching 63/1 at 5 *min* Free passage of solutes through the extracellular spaces of the skin may be interfered with by tight junctions (HASHIMOTO 1971) or other barrier forming structures (ELIAS C

FRIEND 1976) at the intercellular spaces of the stratum granulosum while transport through the loose interstitial collagen matrix should be as rapid as that through water (LAURENT 1972) Uptake by glands of the skin may prevent return to the blood LAGEMANN (1975 1976) found equal blood and skin concentrations of diatrizoate after a 4 to 7 hour infusion

The bone marrow diatrizoate concentration curve had an absolute level about 10 per cent of that of plasma diatrizoate and appeared to refl ct this curve after some delay which could be accounted for by the sluggish marrow circulation The albumin and diatrizoate spaces were of approximately equal magnitude a finding consistent with evidence that bone marrow does not contain an extracellular compartment separate from the plasma space (DOBSON et coll 1975)

To explain lower serum and urine concentrations of meglumine than of iothalamate 10 min after intravenous and intra aortic single dose injections in dogs LASSER et coll (1975) have proposed that the meglumine cation is distributed intracellularly As was shown the diatrizoate distribution volume varies considerably among tissues and changes rapidly with time and it is likely that the pattern for meglumine is highly variable as well The meglumine cation is considerably smaller than diatrizoate and its transcapillary diffusion and spread through the extracellular spaces should be even more rapid and hence more extensive than that of diatrizoate Although a minimal intracellular uptake of meglumine cannot be excluded it is our opinion that the results of LASSER et coll (1975) indicate a more rapid extracellular fluid uptake of meglumine than of diatrizoate

Whether significant intracellular uptake of contrast medium occurs in vivo remains unresolved The findings of LOHR et coll (1974) using electron microscopic autoradiography may not be applicable to the in vivo situation Renal clearance investigations suggest that the distribution volume of diatrizoate (BURBANK et coll 1963 MORRIS et coll 1965) and iothalamate (OTT & WILSON 1975) does not differ significantly from that of inulin or o iodohippurate However the true distribution volume of diatrizoate may be closer to the sulfate space e g true extracellular space (CHOW & WOODBURY 1965 WALSER 1967) than to inulin space since progressive uptake in glandular tissues was demonstrated

In human material a reasonably good equilibrium is obtained at 10 min as shown by CATTELL et coll (1967) This is in good agreement with the present experimental findings However since it was observed that extravascular distribution is an early and major component of the distribution volume we disagree with the interpretation of NEW & SCOTT (1975) who *explain that the fall in plasma* contrast concentration during the first 10 min after inje ti n mainly reflects distribution into plasma volume

The large extravas ular diatrizoa f action (Fig 3) demonstrates graphically how the greater part of dose of uro phic contrast media is wasted through rapid extravascular uptake ontrast enh ement in computed tomography makes use of the differing extra ular uptake contrast media (GADO et coll 1975 GADO &

PHELPS 1975) but the early temporal variation in relative enhancement between tissues must be taken into account (KORMANO & DEAN 1976) in the evaluation of the potential of enhancement

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SUMMARY

A mixture of ^{125}I labeled meglumine diatrizoate and ^{131}I labeled human serum albumin was injected into the femoral vein of 26 anesthetized male rats Measurements of the activities in cardiac blood and in different tissues of the lower extremity and in the testis were performed at time intervals ranging from 5 s to 5 min after injection The determination of tissue uptake and distribution volumes of diatrizoate showed widely differing accumulation of contrast medium Over 50 per cent of the intravenous bolus of diatrizoate was extravascular at 40 s

ZUSAMMENFASSUNG

Eine Mischung von ^{125}I gezeichnetem Meglumindiatrizoat und ^{131}I gezeichnetem humanen Serumalbumin wurde in die Vena femoralis von 26 narkotisierten mannlichen Ratten injiziert Die Aktivitaten wurden im Herzblut und in verschiedenen Geweben der hinteren Extremitat und den Hoden zu verschiedenen Zeitintervallen zwischen 5 Sekunden und 5 Minuten nach der Injektion gemessen Die Bestimmung der Gewebsaufnahme und der Verteilungsvolumina von Diatrizoat zeigte stark unterschiedliche Kontrastmittelaufnahmen Über 50 Prozent des intravenös injizierten Diatrizoates war nach 40 Sekunden extravaskular

RÉSUMÉ

Un melange de diatrizoate de méglumine marque à ^{125}I et de sérum albumine humaine marqué à ^{131}I a été injecté dans la veine femorale de 26 rats males anesthésies Les mesures des activités dans le sang cardiaque et dans différents tissus du membre posterieur et dans le testicule ont été exécutées à des intervalles de temps allant de 5 secondes à 5 minutes après l injection La détermination de la fixation tissulaire et les volumes de distribution du diatrizoate ont montré des accumulations de moyens de contraste très différentes Plus de 50 pour-cent du diatrizoate injecté par voie intraveineuse est extravasculaire au bout de 40 secondes

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FROM THE RADIOLOGIC UNIT AND RENAL WARD OF THE IVTH DEPARTMENT OF MEDICINE
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PROGNOSTIC VALUE OF ANGIOGRAPHY IN EARLY FAILURE OF RENAL TRANSPLANTS

LEENA LAASONEN

Dysfunction of the transplant is common in the early postoperative phase, especially in patients with cadaver transplants. The failure may be due to ischaemia, anastomotic (operative) complications, or rejection. During the anuric period it is often difficult to differentiate between these conditions and to assess the viability of the transplant. If irreversible failure could be recognised, unnecessary immunosuppressive treatment could be avoided.

Angiographic features of severe rejection have been reported. NILSON et coll. (1968) found that the circulation time was prolonged in patients with irreversible rejection. They also observed that the peripheral arteries did not fill and that the nephrographic effect was slight or absent. Using magnification angiography FOLEY et coll. (1975) reported total absence of demarcation of the cortex in cortical necrosis. A systematic evaluation of the angiographic features of irreversible rejection in the early postoperative period is now reported.

Material

The group with irreversible rejection consisted of 18 patients. 17 had received the kidney from cadaver donors and one from a living relative. In 11 of these patients the transplanted kidney never functioned well enough for dialysis to be discontinued and in the remaining 7 irreversible rejection developed within one month of trans-

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Table 1

Graft match ischaemic times and immediate function

Transplant	HL A match		Warm ischaemia (min)			Cold ischaemia	Immediate function
	A–B	C–D	0–14	15–29	30–70		
Lost (18)	2	16	11	6	1	4 h 51 min to 22 h 19 min (mean 10 h 55 min)	8
Successful (20)	4	16	16	2	2	2 h 10 min to 27 h (mean 8 h 50 min)	7

Table 2

Findings in all 47 angiographies

Transplant	Arterial circulation time (s)			Abnormal tapering	Filling of arcuate arteries		Filling of interlobular arteries			Nephrographic effect			Oedema	
	2	2 5–3 5	4		−	+	−	+	++	−	+	++	−	+
Lost	3	10	12	13	8	17	21	2	2	7	11	5	11	14
Successful	11	11	0	0	0	22	5	2	15	1	4	17	13	9

plantation In all patients rejection was confirmed by percutaneous biopsy or at nephrectomy In these patients 25 angiographies were performed The series does not include patients who lost their transplants because of operative complications those with obliteration of the renal artery demonstrated at angiography or those who died from complications not related to failure of the transplant

The control group consisted of 20 patients who despite postoperative dysfunction later obtained satisfactory renal function with a serum creatinine level below 2 2 mg/100 ml All the patients in this group received cadaver kidneys The follow up time was 1 to 2 5 years In these patients 22 angiographies were performed within one month of transplantation all on clinical indications

Regarding the HL A match grades and ischemic times there were no significant differences between the two groups (Table 1)

Methods

The angiography was performed by non selective catheterization of the ipsilateral femoral artery Twenty ml Isopaque 60 % (350 mg I/ml) was injected at a pressure of 2 5 kg/cm² at the orifice of the internal iliac artery The whole series of exposures was completed within 12 to 15 seconds Air gap magnification (2 1 LAASONEN et

Fig 1 Non functioning transplant Second angiography 30 days after transplantation Rather wide interlobar arteries with rapidly decreasing calibre No filling of arcuate arteries no nephrography The arterial circulation time was 5 s Microscopy Severe rejection with extensive cortical necrosis

coll 1976) was used for evaluation of the cortical arteries in selected cases No significant complications were encountered

The following angiographic features were assessed without knowledge of the patients clinical condition the appearance of the interlobar arteries the degree of filling of the arcuate and interlobular arteries the nephrographic effect which was graded as absent slight or good the presence of oedema (indicated by stretching of the interlobar arteries or the arcuate arteries) The arterial circulation time was determined in two ways from the passage time of the contrast medium (NILSON et coll) and from the arterial emptying time (KAUDE et coll 1970) When the circulation time was normal or moderately prolonged the two methods gave comparable results When the circulation was n ore imp r d the arterial emptying time was usually considerably longer than th ag t f the contrast medium Definite abnormality was thus easier to recog orn t erial emptying time

R s and Discussion

The angiographic fi nted in Table 2 Three angiographic eatures occurred only in the h ersible rejection (1) an arterial emptying time

a b

Fig 2 Accidental passage of air in the perfusate during transport Primary oliguric graft failure later severe rejection the transplant never functioned adequately a) Angiography 1 days after transplantation Interlobar arteries stretched but with normal gradual tapering Arcuate arteries visible no filling of interlobular arteries (b) Angiography after 41 days Interlobar arteries wider than in (a) with abnormal tapering No filling of the arcuate arteries

of 4 seconds or more (2) non filling of the arcuate arteries and (3) abnormal tapering of the interlobar arteries i e a rapid decrease in the caliber of the wide interlobar arteries before the level of the arcuate arteries (Fig 1) The presence of one or more of these appearances allowed correct prognostic evaluation in 13 of the 18 patients with irreversible rejection In 11 of these 18 patients the graft never functioned satisfactorily and they all had at least one of the 3 features of irreversibility in 2 patients the initial examination was inconclusive but irreversibility could be predicted when the angiography was repeated (Fig 2)

Among the 7 grafts that were lost after functioning for some time irreversibility was indicated in 2 patients only The other 5 patients had no angiographic indication of irreversibility These patients were used to assess the prognostic value of the degree of filling of the interlobular arteries the degree of nephrographic effect and the presence of oedema The angiographic appearances in these patients were compared with those in the 10 patients with reversible rejection periods The angiographic findings in these patients appear in Table 3 None of the features recorded or any combination of these were specific for the patients with irreversible rejection None of these patients had such poor nephrography that the kidney could not be outlined

Table 3

Angiographic findings in patients with irreversible rejection and inconclusive films and reversible rejection

	Case No	Circulation times (s)	Filling of interlobular arteries	Nephrographic effect	Oedema
Irreversible rejection	232	2	+ +	+ +	−
	234	2		−	−
	313	2 5	−	+	−
	340	3	−	−	−
	342	2	+ +	− −	−
Reversible rejection	225	2 5	+	− +	−
	233	3 5	−	−	−
	236	3	+ +	− −	−
	284	2	−	−	−
	289	3	+ +	−	−
	310	3	+	− +	−
	316	2 5	+ −	− +	−
	347	2 5	−	−	−
	349	2	+ +	+ −	−
	350	1 5	+ +	+ +	−

Table 4

Time relations (days) between transplant function the onset of clinical symptoms of rejection and angiography in 9 patients with irreversible rejection

Case No	Duration of initial transplant function	Time from onset of rejection to angiography	Duration of transplant function after angiography	Angiographic signs of irreversibility
227	2	9	0	+
264	0	8	0	+
358	8	4	1	+
340	10	4	2	−
313	15	4	6	−
232			[illegible]	−
234	0	−	6	−
342		1	[illegible]	−
279	[illegible]	1	12	+

which would suggest [illegible]tal absen[illegible]e of accumulation of contrast medium within the outer part of the c[illegible] by FOLEY et coll regarded as indicating cortical necrosis In the present material it occurred only in combination with other features indicating irreversibility

Book review

Radiology in renal failure By Harry J Griffiths 296 pages with 297 figures and 16 tables W B Saunders Philadelphia 1976

The practice of kidney transplantation and dialysis has had the result that an increasing number of patients with impaired or total cessation of renal function are requiring continuous medical care Complications from different systems of organs are common and have been reported in many articles during the past 10 to 20 years This monograph is the first to cover all the abnormalities arising in connection with kidney diseases and more especially in renal failure

An exc llent and comprehensive chapter on renal osteodystrophy together with a chapter on cardiopulmonary changes comprise slightly more than one third of the whole book A separate well arranged clear and concise chapter entitled Angiography of Renal Failure by D F Adams N K Hollenberg and H L Abrams is one of the best sections in the book There are also a few short chapters dealing with more specialized procedures such as bone mineral analysis xeroradiography ultrasound and radionuclide examinations

The book contains many illustrations but unfortunately their quality is not always of the best *especially in the case of those illustrating pulmonary abnormalities* For radiologists some of the sections might perhaps be regarded as unnecessarily elementary in that descriptions are given of contrast media and the practical performance of urography However this may serve the purpose of making the presentation more interesting and comprehensible for other scientists besides radiologists

In its capacity as the first monograph hitherto available on a wide and important sector of the medical services the book fills a considerable need As such it will be of interest not only to radiologists nephrologists and urologists but also to all physicians who come into contact with this category of patient Because of its best and most important sections those on the skeletal and cardiopulmonary abnormalities and on nephroangiography it can be recommended as valuable reading matter for workers in many different spheres of medicine

Bo Lundstrom

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ANGIOGRAPHY IN PHEOCHROMOCYTOMA OF THE URINARY BLADDER

Report of a case

S O HIETALA J H TEXTER JR and D B CRANE

Angiography is considered a safe procedure for the preoperative diagnosis and exact localization of pheochromocytoma (BOIJSEN et coll 1966 CAMPBELL et coll 1974) provided adequate pharmacologic preparation of the patients and continuous monitoring of the blood pressure during the angiographic procedure are performed With the percutaneous femoral approach no fatal complications have been reported following angiography in patients with pheochromocytoma during the last 20 years The angiographic technique and findings have been discussed in many previous reports (LANNER & ROSENCRANTZ 1970 ROSSI 1968 ROSSI et coll 1968 SUTTON 1975 CHRISTENSON et coll 1976) These angiographic reports were based on patients with either adrenal (BOIJSEN et coll LANNER & ROSENCRANTZ) para aortic (ROSSI SUTTON) intrathoracic tumors (MCNEIL et coll 1970) or with tumors in the organ of Zuckerkandl (MELICOW et coll 1977) It has been reported that more than 10 per cent of the pheochromocytomas occur in extra adrenal sites (ROSSI et coll) Multiple tumors are found in about 15 per cent of adults and in 40 per cent of children

Localization of pheochromocytoma in the urinary bladder may be explained by the occurrence of ectopic chromaffin tissue in the wall of the bladder (HIGGINS & TRESIDDER 1966) Since the first case published by ZIMMERMAN et coll (1953) 35 additional cases of vesical pheochromocytoma have appeared in the literature Angiography of pheochromocytoma of the urinary bladder has been reported previously only in one single case (CAMPBELL et coll 1974) In that case non selective angiography

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demonstrated a mass hypervascular both in the arterial and the capillary phase. Therefore it seems appropriate to add a recently diagnosed case of vesical pheochromocytoma where angiography contributed significantly to the final diagnosis and exact localization of the tumor

Case report

A 20 year old black female was noted to have hypertension on routine obstetric office visit four months into her first pregnancy The blood pressure was treated with thiazide and she delivered a healthy baby at full term She experienced no other remarkable symptoms referrable to the pheochromocytoma during pregnancy and delivery On postpartum visits her blood pressure was moderately elevated She was feeling well but 5 months postpartum developed central vision loss in the right eye and also blurred vision of the left eye The patient was therefore referred to hypertension clinic

The past urologic history was negative except for a kidney infection with mild bilateral hydronephrosis During several months she noticed episodic headaches palpitations and a salty taste in her mouth during voiding These symptoms were so severe that she did not urinate until her bladder was maximally distended

The physical examination was essentially negative Her blood pressure on admission was 130/40 mmHg Pulse was regular at 86 per minute Urinalysis was negative Hemoglobin was 13 7 gram per cent White cell count was 11 300 An ophthalmologic examination revealed hemorrhages and exudates in both eyes in the right greater than in the left During hospitalization her blood pressure was recorded repeatedly at different times during the day and night and also before and after micturition A blood pressure elevation up to 300/170 mmHg together with severe headache and palpitations occurred during micturition In order to prevent the paroxysmal blood pressure elevations the bladder was drained by Foley catheter During the insertion of the catheter the blood pressure rose from 140/100 to 260/160 mmHg Intravenous administrations of an alpha adrenergic blocking agent Regitine 5 mg 2 (phentolamine CIBA) brought the blood pressure to the original level within 5 min

The association of headaches and hypertension with palpitation during micturition suggested the diagnosis of pheochromocytoma Urinary catecholamines were collected to confirm the diagnosis Angiography was performed to confirm the presence and localization of the tumor in the bladder

Angiography The patient was prepared before the angiographic examination with an alpha adrenergic blocking agent Dibenzyline 10 mg (phenoxybenzamine hydrochloride Smith Kline & French) daily for four days The blood pressure pulse rate and cardiac activity were continuously monitored throughout the angiographic procedure A vein cannula was inserted for immediate phentolamine injection in case of imminent hypertensive crisis The endocrinologist was present during the entire procedure

Both femoral arteries were catheterized percutaneously and polyethylene catheters (Red Kifa OD/ID 2 20 mm/1 20 mm) were placed selectively in both internal iliac arteries The bladder was inflated with 150 ml CO_2 introduced through the Foley catheter The contrast medium (Renografin 76% diatrizoate Squibb) was injected with an automatic injector simultaneously through both catheters The injection rate was 10 ml per second for 3 seconds The rate of exposures was 2 films per second during the first 4 seconds followed by one film per second for an additional 11 seconds Subsequently a selective examination with one catheter was performed on the side of the tumor with the patient in 30 degrees right posterior oblique position Fifteen ml of the same contrast medium were injected with an injection rate of 10 ml/s and films were exposed as before One of the selective catheters was then

a b

Fig 1 Selective bilateral angiography of the urinary bladder (subtraction films) a) arterial b) capillary phase Markedly increased number of tortuous vessels within the tumor in the left half of the bladder Extensive arterial supply (→) from the other side Accumulation of contrast in drum in the late arterial phase and also early venous filling

b

Fig 2 Selective examin t or side in right po terior obliqu position (subtraction films) a) arterial b) venous cer arteries (→) at the periphery of the tumor and small p r forating branches arra 3 n a to wheel fashion Th ma s is drain d by extrem ly widened and tortuous veins

Fig 3 Dichromate fixed material stained with the haematoxylineosin Part of the pheochromocytoma showing a cellular neoplasm and a highly vascular stroma Dark chromaffin granules in the cytoplasms The nuclei are rounded rather uniform in size and shape ×250

removed and replaced by a pig tail catheter (Cook) The tip of the catheter was placed above the origin of renal arteries and 50 ml of the contrast medium were injected with an injection rate of 25 ml/s Finally a selective examination was performed of both renal arteries with injection of 15 ml of contrast medium on both sides The total amount was 125 ml which was delivered in 5 separate injections

During each injection of contrast medium the blood pressure rose to about 200 mmHg systolic It returned to previous levels with repeated intravenous injections of phentolamine (Regitine CIBA) 5 mg at a time Because of blood pressure spikes further angiography to exclude thoracic pheochromocytoma was not thought advisable The clinical diagnosis of pheochromocytoma of the bladder was confirmed angiographically

Appearance of the tumor Within the left half of the bladder a hypervascular mass was demonstrated (Fig 1 a) The mass received part of its blood supply from the opposite side The tumor seemed to be supplied by multiple arteries at the periphery of the mass (Fig 2 a) Smaller branches arose from these arteries and perforated the tumor like the spokes of a wheel In the capillary phase (Fig 1 b) an intense and rather homogeneous accumulation of contrast medium in the mass occurred which had a surface area of approximately 4 cm × 6 cm Considerably dilated and tortuous veins were already visible in the early capillary phase (Fig 1 b) and drained the mass to both sides (Fig 2 b) The right posterior oblique projection revealed that the tumor was located anteriorly and superiorly in the bladder The outer limits of the bladder wall could not be defined and it was therefore impossible to decide

whether the tumor involved perivesical tissue or not Additional tumors in the abdominal region were not found on abdominal angiography Selective bilateral nephroangiographies offered more detailed information especially of the inferior suprarenal vessels which were normal on both sides Routine cystography failed to provide any additional diagnostic information

Operation After induction of general anesthesia cystoscopy was performed On the left anterior and superior bladder wall a large indentation was evident It was quite distant from both ureteral orifices and covered with normal appearing bladder mucosa Blood pressure elevations occurred as the bladder was distended during the cystoscopy but was easily brou ht under control with medication

Immediately following cystoscopy surgery was performed The tumor was widely excised with a 2 5 cm margin of normal bladder wall When the tumor was lightly touched the blood pressure again rose to 200/110 mmHg The continuous phentolamine drip restored the blood pressure to near normal levels Both suprarenal areas were explored and were found to be normal No abnormal masses were palpable in the abdomen or pelvis The subsequent postoperative convalescence of the patient was uneventful Postoperative blood pressure promptly returned and remained in normal range

Microscopy Chromaffin paraganglioma (pheochromocytoma)

Discussion

The symptoms of headache palpitations and episodic hypertension on micturition are typical of urinary bladder pheochromocytoma Since the tumor is usually situated between the muscle fibers of the bladder wall the catecholamines (adrenaline or noradrenaline) tend to be released into the circulation when the bladder is contracting or when it is very distended This explains the paroxysmal hypertension and other symptoms specifically related to micturition which are characteristic clinical features of vesical pheochromocytoma (CUMMINS et coll 1969) These symptoms suggest a diagnosis preoperatively The most important aid to the clinical diagnosis is the estimation of catecholamines in the blood or urine Elevated values are observed in the vast majority of cases of pheochromocytoma Determination of vanil mandelic acid (VMA) in the urine has been found to be useful The biochemical and pharmacologic tests are confirmative if they are positive However in many cases all the classical signs and symptoms are not present biochemical tests may be normal (DOCTOR et coll 1972 HIGGINS & TRESIDDER 1966) Hypertension may be sustained rather than paroxysmal Because a tumor frequently cannot be palpated and because it may be multiple and occur at extra adrenal sites radiography is mandatory to confirm the presence o tumor and to localize it Pheochromocytomas may occasionally be f und unexpectedly in cases where hypertension is angiographically evaluated Therefore the rad ogist has to be familiar with the angiographic characteristics and the potential hazards of the angiographic procedure

Pheochromocyt as have a fai ly characteristic angiographic appearance (BOIJSEN et coll 1966 CAMPBELL et coll 1974 LANNER & ROSENCRANTZ 1970 CHRISTENSON et coll 1976) The tumors have similar angiographic appearances either they are situated in or c ntiguous to the adrenals or they are entirely extra adrenal The

feeding arteries in almost all the reported cases as well as in the present case have been described following the periphery of the neoplasm The vessels within the tumor vary in caliber and are similar to the appearances in cases of neovascularity In the presented case also a remarkable arterial supply from the opposite side to the tumor existed An intense accumulation of contrast medium within the tumor sometimes with a less vascularized center has been reported as characteristic for pheochromocytoma It is evident that pheochromocytoma of the bladder also shares these characteristics with those of other locations The predominant angiographic finding was the early venous filling and the extremely dilated draining veins Similar venous changes of less magnitude have been observed in adrenal pheochromocytomas but were not described in the single case of angiography of vesical pheochromocytoma which was reported previously (CAMPBELL et coll)

It is apparent that the angiographic appearance of pheochromocytoma of the urinary bladder is not pathognomonic Similar findings except the venous abnormalities have been observed previously (HASSLER & HIETALA 1974) in cases of urinary bladder carcinoma It was not possible to decide angiographically whether the tumor was invasive or not Therefore angiography did not allow differentiation between a malignant and benign tumor

The surgical treatment of the tumor requires expert management due to the wide fluctuations in the blood pressure observed during the manipulation and excision of the tumor In the present case the blood pressure elevations were treated by a continuous phentolamine drip and the resection was without complications The operative mortality for primary pheochromocytoma has been previousl reported as less than 5 per cent (HARRISON et coll 1974)

The microscopic diagnosis which sometimes may be difficult (MELICOW et coll) indicated a benign tumor in the present case It must be pointed out that a distinction between benign tumors of multifocal origin and primary malignant tumors (HARRISON et coll 1974 MOLONEY et coll 1966) may not be easy In pheochromocytoma the diagnosis of malignancy does not rest on the cellular characteristics of the tumor nor upon the infiltration of the organ of origin since considerable degrees of cellular variation and local infiltration may be found in tumors which behave in a perfectly benign fashion To confirm malignancy secreting cells must be demonstrated at a site where chromaffin tissue does not usually occur (HIGGINS & TRESIDDER 1966) Benign tumors have a multifocal origin in approximately 10 per cent of cases but tumor cells are confined to tissue which contains chromaffin elements

Other features which may suggest a diagnosis are the shape and the color of the tumor Nearly all reports have described a rounded mass covered by intact or only superficially ulcerated normal looking epithelium Most of the tumors have been described as yellow or brown darkening on fixation in formalin (DOCTOR et coll 1972) This brown discoloration of the fixative which also occurred in the case presented has been reported as another indication of pheochromocytoma

SUMMARY

A case of pheochromocytoma of the urinary bladder in a 20-year old female is reported This is the 36th reported case in the English language literature The patient had classical symptoms of vesical pheochromocytoma with sudden onset of headache palpitations and blood pressure elevation during voiding The provisional diagnosis was arrived at on clinical history laboratory investigations including the estimation of catecholamines and vanil mandelic acid (VMA) The diagnosis was confirmed and the tumor was exactly localized by means of angiography The angiographic appearance of pheochromocytoma of the urinary bladder is not pathognomonic and is similar to that previously described for adrenal pheochromocytoma Angiography is with adequate precautions a safe and useful procedure for ruling out synchronous adrenal or extra adrenal tumors and for exact localization of the bladder tumor

ZUSAMMENFASSUNG

Phaochromocytom der Blase bei einer 20 Jahre alten Frau wird beschrieben Dieses ist der 36 rapportierte Fall in der Englischsprachigen Literatur Der Patient hatte klassische Symptome eines Phaochromocytoms der Blase mit plotzlich einsetzenden Kopfschmerzen Herzklopfen und Blutdruckerhohung wahrend der Miktion Die vorläufige Diagnose wurde aus der klinischen Vorgeschichte den Laboratoruntersuchungen einschliesslich der Unter suchung der Catecholamine und der Vanil Mandel Saure (VMS) gestellt Die Diagnose wurde bestatigt und der Tumor exakt lokalisiert mit Angiographie Das angiographische Bild des Phaochromocytoms der Blase ist nicht pathognomonisch und ist dem adrenalen Phäochromocytom ahnlich Die Angiographie ist mit adaquaten Vorsichtsmassnahmen eine sichere und brauchbare Methode um gleichzeitige adrenale oder extra adrenale Tumoren festzustellen und die Lokalisation des Blasentumors exakt festzustellen

RESUMÉ

Les auteurs presentent un cas de pheochromocytome de la vessie chez une femme de 20 ans C est le 36eme cas publié dans la litterature de langue anglaise La malade avait les signes classiques de phéochromocytome v sical avec debut brutal de céphalees de palpita tions et élevation de la tension arterielle au cours de la miction Le diagnostic provisoire avait ete etabli sur l histoire clinique les e amens de laboratoire y compris le dosage des catecholamines et de l acide v nilmandelique (V MA) Le diagnostic a eté vérifié la tumeur a éte exactement localisee par l angiograph e L aspect angiographique du pheochromocy tome de la vessie n est pas pa hognomor ... et est semblable à celui qui a été décrit pour le phéochromocytome surren l n L angio ... e est avec des precautions convenables une méthode sans dangers et u ... pour s a ... qu il n y a pas en meme temps des tumeurs surrénaliennes ou extrasu ... iennes ... localiser exactement la tumeur vésicale

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY THE NORWEGIAN RADIUM HOSPITAL
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PHLEBOGRAPHIC APPEARANCES OF THE LEFT RENAL AND LEFT TESTICULAR VEINS

H H LIEN and A KOLBENSTVEDT

Phlebography of the renal veins has been reported to be of value in the evaluation of renal carcinoma (FUCHS 1961) congenital venous anomalies (CHUANG et coll 1974 a) left adrenal disease (FIELD & SAXTON 1974) and retroperitoneal masses (COPE & ISARD 1969) It has also been used in the examination of varicocele in men (AHLBERG et coll 1966) and pelvic varicosities in women (CHIDEKEL 1968) using the retrograde flow through the left gonadal vein

Selective phlebography of the left testicular vein has been performed in the evaluation of anorchid patients or patients with undescended testes (JACOBS 1969) and as a supplement to lymphography in the diagnosis of retroperitoneal masses (LIEN & KOLBENSTVEDT 1977 a)

In the literature only sc[illegible]ce information [illegible] available about the normal radiologic appearances of the left re[illegible]l and left te[illegible]ular veins The various anomalies of the l[illegible]ft renal vein must be k[illegible]n for [illegible] catheterization of the renal vein, and to make possible an evalua[illegible]n of the [illegible]ances of the inferior vena cava caused by influx of blood with[illegible] contrast [illegible]m (LIEN & KOLBENSTVEDT 1977 b) When attempting selective cath[illegible]rization [illegible] left testicular vein it is essential to know the most frequent vari[illegible]n of its p[illegible]entry

The purpose of the [illegible]nt rep[illegible] to demonstrate typical phlebographic appearances and the m[illegible]quent [illegible]alies of the left renal and left testicular veins in a material of 100 [illegible] and t[illegible]pare the frequency of anomalies with autopsy reports

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Fig 1

Fig 2a

Fig 2b

Fig 1 Circumaortic venous ring demonstrated by selective phlebography of the left r al vein Retroaortic position of the lower limb was demonstrated in lateral films

Fig 2 a) Phlebography of single retroaortic left renal vein b) Lateral projection A short formed catheter in the vein and a long straight catheter in the aorta The position of the catheter nfirms the retroaortic course of the renal vein

Embryologic aspects The development of the inferior vena cava is a complicated process involving regression anastomoses and replacement of 3 pairs of symmetric longitudinal veins (CHUANG et coll 1974 b) The posterior cardinal and the supra cardinal veins which are dorsal structures the latter pair being the most medial and the subcardinal veins which are ventral structures Normally the posterior cardinal veins do not persist cranial to the common iliac confluence area Anastomoses between the remaining supracardinal and subcardinal veins at the renal level form a circumaortic venous ring which thus dorsally consists of an intersupracardinal anastomosis ventrally of an intersubcardinal anastomosis and laterally of a right and left suprasubcardinal anastomosis

Normally the caudal part of the inferior vena cava is derived from the right supra cardinal vein while the segment at the renal level is formed by the right suprasubcardinal anastomosis and the cranial part (up to the hepatic level) from the right subcardinal vein

Each foetal kidney has a pair of embryonic veins which connect with the circum aortic ring one dorsal which usually atrophies and one ventral which persists Normally the retroaortic limb of the circumaortic venous ring also atrophies so that the medial part of the left renal vein is formed by the ventral preaortic limb of the circumaortic ring Occasionally both limbs persist so that the renal vein in adult life bifurcates to encircle the aorta Rarely the ventral limb atrophies giving rise to

Table 1

Filling of tributary veins following injection into the left renal vein

Vein	No of patients
Left testicular	57
Ascending lumbar	34
Ureteric	12
Adrenal	6
Renal capsular	1
Network near renal hilus	9

a sin le retroaortic l ft renal vein The l ft testicular vein represents the caudal remnant of the left subcardinal vein (ANSON et coll 1948) It is thus a ventral structure and would be expected to enter the ventral limb in cases of persistent circumaortic venous ring

Material and Methods

During the period November 1973 through March 1976 a total of 155 patients admitted to the Norwegian Radium Hospital because of confirmed or suggested testicular tumor were examined by foot lymphography phlebography of the inferior vena cava and s lective phlebography of the left renal and left testicular veins followed by urography The present material consists of 100 consecutive patients in whom all these examinations did not reveal any pathologic changes Ninety-eight of these patients had a malignant testicular tumor without demonstrable metastases while 2 had benign lesions Five patients were aged between 10 and 19 years 54 between 20 and 39 34 between 40 and 59 and 7 patients were more than 60 years old

The phlebographic technique used has been described previously (LIEN & KOLBENSTVEDT 1976) The film focus distance was 90 cm All measurements were made on the films without correction for geometric enlargement Laparotomy with lumbar lymphadenectomy was not performed and the possibility of small metastases is not excluded However retroperitoneal meta tases large enough to produce distortion of the renal or testicular eins would have been demonstrated by the combined lympho phlebo and ur raphic proced The present series of 100 cases was therefore considered to b presentativ ormal group

r

Left renal vein A si preaortic lef l vein was found in 88 cases In one of these the vein divided f hort distanc form a hiatus Ten cases had a persistent circumaortic venous r Fig 1) and id a single retroaortic vein (Fig 2) Super

Fig 3

Fig 4

Fig 5

Fig 3 An ulated appearance of the lower margin of the left renal vein with entry of the left testicular vein at the apex Communication to the ascending lumbar vein

Fig 4 Concavity of the lower margin of the left renal vein on each side of the point of entry of the left testicular vein

Fig 5 Concavity of the lateral lower margin of the left renal vein Considerable run off of contrast medium through a wide communicant to the left ascending lumbar vein which empties into the left common iliac vein

numerary veins that is veins emerging separately from the kidney and terminating separately in the inferior vena cava were never found The entry of the preaortic left renal vein in cases with a single vein or a circumaortic ring was at the level of Th 12 to L 2 The dorsal limb of the circumaortic ring ran an oblique downward course and joined the inferior vena cava at the level of L 3 in 6 cases L 2 in 1 and at the intervertebral disc between L 2 and L 3 in 3 cases The single retroaortic left renal vein (2 cases) entered the vena cava at the level of L 3

Of the 10 cases with a circumaortic ring the upper anterior limb was wider in 9 while the lower posterior limb was wider in one as measured near the inlet into the vena cava

The width of the single preaortic left renal vein near the caval inlet ranged from 1 5 to 3 0 cm (average 2 3 cm) In 81 the width was between 2 0 and 3 0 cm while in 7 it was less than 2 0 cm

In the 2 cases of single retroaortic vein the width was 2 9 and 2 0 cm

The length of the preaortic left renal vein as measured from the medial renal

Fig 6 Selective phlebography of the left testicular vein in cases with persistent circumaortic venous ring. a) The left testicular vein (arrows) enters the preaortic limb but also communicates with the retroaortic limb in this case consisting of two continuous arcades with a communicating branch towards the lumbar plexus at their junction b) The left testicular vein joins the retroaortic limb (arrows) c) The left testicular vein enters the bifurcation of the renal vein The retroaortic limb consists of two continuous arcades

margin to the left margin of the inferior vena cava ranged from 5 5 cm to 9 5 cm (average 7 8 cm)

Retrograde filling of tributary veins after injection of contrast medium into the left renal vein occurred frequently (Table 1)

The inferior margin of the preaortic left renal vein was slightly angulated with the point of entry of the testicular vein at the apex in 23 cases (Fig 3) In 45 cases the inferior margin had a downward concavity either medial or lateral to the point of entry of the testicular vein or on both sides (Fig 4) As a result of this downward concavity or angulation of the lower renal vein margin a small wedge of contrast medium was often seen at the point of entry of the testicular vein In 3 cases the border of the concavity was at the site of entry of another vein This tributary was in all 3 cases a wide communication from the ascending lumbar vein (Fig 5)

In 75 cases the point of entry of the left testicular vein could be identified at renal phlebography from the appearance of the lower margin of the renal vein or filling of tributary veins or both

Fig 3

Fig 4

Fig 5

Fig 3 Angulated appearance of the lower margin of the left renal vein with entry of the left testicular vein at the apex Communication to the ascending lumbar vein

Fig 4 Concavity of the lower margin of the left renal vein on each side of the point of entry of the left testicular vein

Fig 5 Concavity of the lateral lower margin of the left renal vein Considerable run off of contrast medium through a wide communicant to the left ascending lumbar vein which empties into the left common iliac vein

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Of the 10 cases with a circumaortic ring the upper anterior limb was wider in 9 while the lower posterior limb was wider in one as measured near the inlet into the vena cava

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In the 2 cases of single retroaortic vein the width was 2 9 and 2 0 cm

The length of the preaortic left renal vein as measured from the medial renal

a

b

Fig. 8 Selective phlebography of left testicular vein a) A p projection The testicular vein divides into two main branches in its cranial part, with additional filling of some small accompanying vessels The tip of the catheter lies in the lateral branch Large tributary from the dorsolateral abdominal wall at the level of the iliac crest b) Lateral projection The lateral branch (arrows) lies posterior to the m dial one

Left testicular vein At phlebography this vein was filled to a greater or lesser degree in 57 patients (Table I) At selective phlebography of the left testicular vein (Fig 7) retrograde filling was achieved in 92 patients in 17 of these less than 5 cm was d monstrated In the remaining 8 patients the attempts were unsuccessful probably du to valves although these could not be demonstrated with certainty

Valves were clearly demonstrated in 50 patients (Fig 7) The width of the left testicular vein was measured 3 cm below the renal vein inlet Measurement closer to th renal vein was considered unreliable becau of occasional spasm following catheterization Due to unsa isfactory filling duplication or even triplication at the level the width could not b stated with certainty in 30 patients In the remaining

Table 2

Filling of tributary veins following injection into the left testicular vein

Vein	No of patients
Lateral abdominal wall tributary	18
Ascending lumbar	12
Renal capsular	5
Ureteric	4
Communication to left common iliac vein	2
Communication to inferior mesenteric vein	1
Network near renal hilus	12

cases the width ranged from 2 mm to 7 mm (average 5 mm) No significant difference was found in the width of the left testicular vein at the time of the examination in patients operated upon 4 to 8 weeks previously with left or rightsided orchidectomy

The frequency with which tributaries were filled following selective injection into the left testicular vein appears in Table 2 Duplication of the testicular vein was demonstrated in 22 patients while in 11 triplication for a shorter or longer distance existed The testicular vein crosses in front of the ureter in the upper left lumbar region (Figs 3 6c 7 8) The crossing point was demonstrated in 62 patients 9 of these had a corresponding impression in the ureter without any sign of ureteric obstruction

Discussion

The occurrence of a persistent circumaortic ring in 10 of the 100 cases corresponds well with previous autopsy experiences Thus PICK & ANSON (1940) found this anomaly in 16 8 per cent of cases REIS & ESENTHER (1959) in 6 0 per cent and SEIB (1934) in 9 1 per cent In these series a single retroaortic vein was found in 3 4 2 5 and 1 7 per cent respectively figures which correspond with the present 2 cases The phlebographic appearances of the circumaortic ring have been described by KOTTRA & CASTELLINO (1970) CHUANG et coll (1974 a) and FIELD & SAXTON in small materials

The existence of a retroaortic vein (single or as part of a persistent circumaortic ring) must be borne in mind at cavography so that intraluminal filling defects caused by influx from these veins are not evaluated as pathologic (LIEN & KOLBENSTVEDT 1977 b) Entry of the left renal vein at the level of the intervertebral disc between L 2 and L 3 or lower strongly suggests the presence of a retroaortic vein In the present series the preaortic renal vein was never seen to enter the inferior vena cava at a level lower than L 2

The anomalies of the left renal vein are also important when renal venous blood is sampled for renin determination and at adrenal phlebography The left adrenal vein being derived from a ventral structure (the cranial remnant of the left subcardinal vein) enters the upper preaortic limb in cases of persistent circumaortic

ring Attention should be drawn to the possible existence of a retroaortic vein during retroperitoneal operations e g aortic (BRENER et coll 1974) and renal surgery

The upper limb of a circumaortic ring was wider in 9 of 10 cases which coincides with the previous autopsy reports of SEIB and ANSON et coll

The most frequent site of entry of the testicular vein was found near the bifurcation of the renal vein and only one of 10 joined the retroaortic limb This corresponds well with the report of SEIB He described 16 autopsy cases with a circumaortic venous ring in only one of these the left testicular vein joined the retroaortic limb while in 12 the entry was near the bifurcation This finding is not surprising as the left testicular vein represents the caudal remnant of the left subcardinal vein which is located ventrally

Supernumerary left renal veins which emerge and terminate separately were reported in 1 0 per cent of cases by PICK & ANSON but was not found in the present material These authors reported hiatus formation of the left renal vein in 6 7 per cent of autopsy cases as compared to only one case in the present series The reason for this discrepancy may be that a small hiatus is not demonstrated at phlebography due to superimposition

The width of the single preaortic left renal vein near the inlet into the vena cava was found to be less than 2 0 cm in 7 patients only A considerable run off of contrast medium via the ascending lumbar vein (Fig 5) occurred in 5 of these cases which is in agreement with the report of COPE & ISARD This means that a narrow left renal vein with filling of collaterals may occur as a variation without necessarily indicating pathologic obstruction

The frequency with which tributaries were filled following injection into the left renal vein (Table 1) does not reflect the real frequency of such communications The ascending lumbar vein (including parts of the lumbar plexus) was filled in 34 cases only while PICK & ANSON reported from autopsy cases communications in 68 8 per cent and FAGARASANU (1938) in 91 5 per cent AHLBERG et coll (1967) found communications to the lumbar plexus in 75 per cent of cases examined with phlebography of the left renal vein However only about one third of their patients were considered normal while two thirds had pelvic varicosities or scrotal varicocele In addition their patients were examined in erect position with repeat examinations in the recumbent position in about half of the subjects For this reason and because of differences in the amount of contrast medium administered their series is not readily comparable to the present one

The point of entry of the left testicular vein into the left renal vein could often be predicted from the appearance of the renal vein The concavities of the inferior margin of the preaortic left renal vein may easily be erroneously evaluated as tumor impression Although laparotomy was not performed this appearance was considered as a normal variant because no abnormality was demonstrated at the supplementary lymphography from the foot cavography and urography The cause of these concavities is not clear they were not observed in retroaortic renal veins

De Schepper (1972) described 2 cases of compression of the left renal vein between aorta and the superior mesenteric artery with narrowing and collateral vein development. This phenomenon was not observed in the present series.

Valves in the left testicular vein were clearly demonstrated in 50 patients and were probably present in the 8 additional patients in whom selective phlebography was unsuccessful. Occasionally valves that offered resistance to the introduction of the catheter could be passed with the aid of a mandrin. The frequency of valves in the present material corresponds well with the autopsy material of Ahlberg et coll. (1965) who found valves in 43 of 79 specimens. They examined only the upper 10 cm of the vein and nearly all valves were found within 1 cm from the renal vein inlet. In the present material more caudally located valves were also demonstrated.

No difference was found in the average width of the left testicular vein in patients with previous left- or rightsided orchidectomy. Thus following removal of the testis a reduction of the blood flow would be expected, but no reduction of the width of this vein was found. Neither was thrombotic occlusion observed. The reason may be the occurrence of tributary veins which in reality probably are more frequent than observed at phlebography (Table 2). A tributary from the dorsolateral abdominal wall (Fig. 8) was demonstrated in 18 cases. Previously the testicular veins were examined by injection into the funicular part. In cases with metastatic obstruction of the cranial part of the vein, this abdominal wall tributary served as an important collateral (Kolbenstvedt et coll. 1975).

Duplication of the left testicular vein, which occurred in 22 patients, most commonly consisted of a narrow accompanying vein for a shorter or longer distance (Fig. 7). Occasionally separate entry into the left renal vein was observed. The more lateral the point of entry, the more dorsal was the position of the vein in lateral projection (Fig. 8). This fact is of importance when forward or backward displacement is estimated on lateral films.

SUMMARY

The normal phlebographic appearances of the left renal and left testicular veins are described, based upon the findings in 100 patients admitted because of confirmed or possible testicular tumor. The patients had no metastases demonstrated at foot lymphography, uro-graphy and phlebography of the inferior vena cava.

ZUSAMMENFASSUNG

Das normale phlebographische Aussehen der linken Nierenvene und der linken Hodenvene wurde auf der Basis von Befunden bei 100 Patienten, die wegen eines festgestellten oder vermuteten Hodentumors eingewiesen worden waren, beschrieben. Durch Lymphographie, Urographie und Phlebographie der Vena cava inferior wurden keine Metastasen nachge-wiesen.

RESUMÉ

Les auteurs decrivent les aspects phlébographiques normaux de la veine renale gauche et de la veine testiculaire gauche en se basant sur les examens de 100 malades admis pour une tumeur testiculaire confirmee ou possible La lymphographie du membre inferieur l'urographie et la phlebographie de la veine cave inferieure n avait pas mis en évidence de metastase chez ces malades

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR O MORALES) CENTRAL LASARETTET S 351 85 VAXJÖ SWEDEN

ANGIOGRAPHIC DIAGNOSIS IN POLYMYALGIA ARTERITICA

C Å SVENDLER and S SÖDERLUNDH

The term polymyalgia rheumatica was recommended by BARBER (1957) for a disease mainly affecting patients above 50 years of age and characterized by pain predominantly in the shoulder region subfebrility tiredness weight loss and a high erythrocyte sedimentation rate Several authors (OLDBERG 1942 SJOVALL & WINBLAD 1944 and others) noticed that symptoms of a disease well consistent with polymyalgia rheumatica were present in patients with temporal arteritis before the onset of arteritis A detailed description of patients with polymyalgia rheumatica has been given by HAMRIN (1972) In addition to the clinical aspects radiographic and pathologic findings in the great vessels of the shoulder regions were described Because of the arterial lesions he used the term polymyalgia arteritica

The present report is an analysis of the an ographic findings present in 10 patients from HAMRIN s series and in another ents with polymyalgia arteritica to obtain information whet r arterial abn ies exist also in other territories than the temporal one

Material and M s Biopsy rev arteritis of the temporal artery in 9 of the 10 cases in HAMRI ries In the group of patients biopsy was performed in 4 with definite s of temp rteritis in 3 In the fourth case the diagnosis of arteritis was nc nfirmed but patient as well as the remaining patients of

Submitted for pu ion July 1976

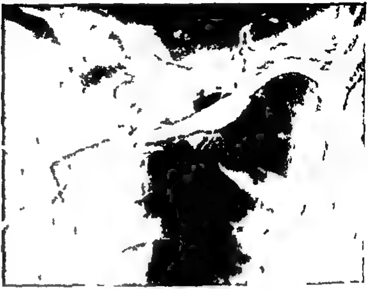


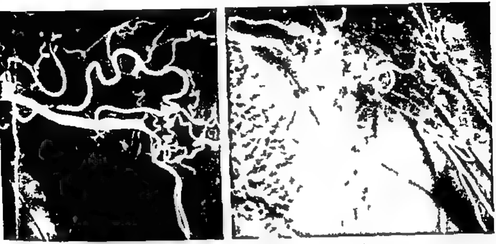
Fig 1 A 69 year-old female Angiography of the brachiocephalic trunk Marked stenosis and aneurysmal widening of subclavian artery

the second group presented a clinical picture quite consistent with polymyalgia arteritica

Of the 20 patients 17 were females and 3 males The age ranged between 64 and 79 years, the mean age being 77 years Initially thoracic aortography was performed but later selective angiography of the subclavian artery or the brachiocephalic trunk was carried out routinely the femoral route being used in all cases The left subclavian and axillary arteries were examined in 19 patients and the right in 11

Results

The vascular lesions had a fairly characteristic appearance and localization consisting of arterial stenosis and sometimes of poststenotic dilatation aneurysmal widening was found in some cases (Fig 1) The stenosis was classified as slight moderate i e less than 50 per cent narrowing and considerable more than 50 per cent (Table) The length of the stenosis varied from some millimeters to more than 10 centimeters As a rule the arterial wall was smooth but with a successive tapering (Fig 3) The lesions were mainly confined to the subclavian and axillary arteries exceptionally stenoses were also found in the vertebral posterior circumflex humeral and subcapsular arteries at their origin from the subclavian and axillary arteries respectively Abnormalities were never observed in the axillary artery more distally than at the origin of the deep brachial artery In considerable stenosis or total obliteration collateral circulation had developed (Fig 2) The most prominent constrictions were located just distally to the origin of the subcapsular artery total obliteration was only found in this region



a b

Fig. [illegible] A 76-year-old female Left subclavian angiography Occlusion of axillary artery Minimal smooth stenosis of subclavian artery Extensive collateral circulation to brachial artery

Discussion

All patients had the clinical diagnosis of polymyalgia arteritica The main criteria for this diagnosis were rheumatic pain most commonly present in the shoulder region a high erythrocyte sedimentation rate (more than 50 mm/h) as a rule subfebrility or fever of long duration loss of appetite and weight loss Often murmurs were noticed over the axillary arteries and in addition a diminished or absent pulse in the radial artery

In 86 of the 93 patients in HAMRIN's material biopsies were obtained from the superficial temporal artery Arteritis was observed in 51 cases (59%) Also the patients in whom the biopsy specimens did not reveal any arterial lesion presented a clinical picture and course completely consistent with polymyalgia arteritica In spite of the long observation time none of these cases developed rheumatoid arthritis as defined by the standards given by the American Rheumatism Association

Table

Results of 19 left sided and 11 [illegible]ht [illegible]id[illegible]d angiographies in 20 pa[illegible]nt[illegible]

Degree o[illegible] narrowing	Subcl[illegible]y		Axillary artery	
	[illegible]igh[illegible]		Right	Left
Slight	[illegible]		5	8
Mode[illegible]	1		2	2
Cons[illegible]e	–		–	4
Oblite[illegible]n	1		1	1

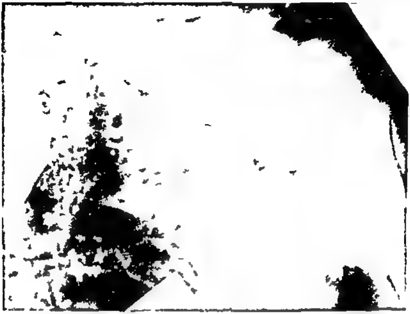


Fig 3 A 72 year old female Thoracic aortography Moderate stenoses of left subclavian and axillary arteries Smooth vessel walls

In the 16 patients in HAMRIN s series who died and in whom autopsy was performed arteritic lesions were observed in the shoulder regions as well as in other regions (ÖSTBERG 1973) These lesions were described as having a patchy appearance with no confluence often only part of the circumference of the artery was engaged Macroscopically narrowing and dilatation of the vessel alternated intimal hypertrophy was also observed At microscopy thickening of the intima medial necrosis with *dissolution of elastic lamella and cellular infiltration often* containing giant cells was found In most cases also adventitial fibrosis existed probably secondary to the medial lesions Similar abnormalities were found also in other than the shoulder regions but in the second group only the main branches in the axillary region were examined

The angiographic appearances of arteritis have been described previously GOTSMAN et coll (1967) investigated 27 patients and observed typical lesions in the main as well as in the smaller arteries of the thorax and abdomen Others like DEUTSCH et coll (1974) have emphasized that the microscopic appearance usually found in Takayashu s arteritis *may exist also in the thoracic as well as the abdominal aorta* with its branches In their material the subclavian arteries were most commonly affected of the thoracic aortic branches Stenosis and also aneurysmal widenings were reported Obliteration and evident stenosis occurred most frequently just distally to the origin of the thyrocervical trunk The thoracic aorta was often deformed narrow segments alternated with dilatation

All patients in the present material had the clinical diagnosis of polymyalgia

arteritica and murmurs over the axillary artery and all were examined by angiography of the subclavian and axillary arteries Lesions were most commonly observed in the vicinity of their branches The smooth appearance of the vessel walls within the stenotic segments is similar to what is encountered in Takayashu s arteritis The regular nature of the arterial constriction makes differentiation between atherosclerosis and Takayashu s arteritis easy (WICKBOM 1957) The same applies to polymyalgia arteritica Differentiation between this condition and Takayashu s arteritis does not seem to be possible at angiography

SUMMARY

Angiography of the main branches of the thoracic aorta was performed in 20 patients with the clinical diagnosis of polymyalgia arteritica Lesions were mainly observed in the subclavian and axillary arteries sometimes also in their branches The angiographic and pathologic appearances of the lesions as well as differential diagnostic considerations are presented

ZUSAMMENFASSUNG

Angiographie der Hauptaste der thorakalen Aorta wurde bei 20 Patienten mit der klinischen Diagnose einer Polymyalgia arteritica vorgenommen Veranderungen waren hauptsachlich in den Arteriae subclavia und axillaris zu beobachten gelegentlich auch in deren Ästen Das angiographische und pathologische Aussehen der Lasionen und die Differentialdiagnostik werden diskutiert

RESUME

Les auteurs ont fait une angiographie des grosses branches de l aorte thoracique chez 20 malades dont le diagnostic clinique était polymyalgie arteritique Ils ont observe des lesions surtout sur les arteres sous clavieres et axillaires, parfois aussi sur leurs branches Ils presentent les signes angiographiques et anatomopathologiques de ces lesions ainsi que des considerations sur le diagnostic differentiel

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ARTERIAL SEGMENTAL VASOCONSTRICTION

Frequency and pathogenetic factors

L E LÖRELIUS U ERIKSON and H ÅBERG

The arteriographic phenomenon that is characterized by regular but inconstant luminal variations is called arterial segmental vasoconstriction in this article (Fig 1) Other authors have referred to this phenomenon with different names Circular vasoconstriction (RATSCHOW 1955 WICKBOM & BARTLEY 1957 KOHLER 1965 BERGQUIST et coll 1971) longitudial contraction (ISCHIKAWA et coll 1973) standing wave (THEANDER 1960 LEHRER 1967) and layer formation between contrast medium and blood (MAYALL 1964) The many names given to this phenomenon suggest that the theories concerning its origin are numerous and varying

The theory of standing waves was refuted by KÖHLER on the basis of mathematical analyses MAYALL s theory of layer formation may be considered disproved by among others NEW (1966) who stated that the phenomenon also was perceived with a horizontal beam direction

The vasoconstriction has often been observed in connection with vascular occlusions especially in embolism ([illegible]EANDER LEHRER) It has also been pointed out that it is common in Raynaud s d[illegible]ase (WICKBOM & BARTLEY) and in angiodyskinesia (AMIR JAHED 1968 HAEGER 197[illegible]) This radiologic phenomenon has been reported from all regions with mediu[illegible] d arteries except the brain and heart

Thus in certain cases segm[illegible] [illegible]soconstriction at angiography indicates a pathologic condition An attempt [illegible] reported to assess the frequency of segmental

Submitted for publication 8 June [illegible]

Fig 1 A 49 year-old woman with a kidney transplantation 2 days previously Sings of a non functioning Scribner shunt were present. Retrograde angiography via the shunt revealed segmental vasoconstriction in the arterial part of the shunt

arterial vasoconstriction in a series of clinical angiographies and to establish more definitive relationships with vascular diseases

Material and Methods

The material consisted of 67 patients with arterial segmental vasoconstriction demonstrated during the years 1967 to 1975 Between January 1967 and July 1972 all patients were included for whom segmental vasoconstriction was noted in the report to the referring physician (total 5 cases) From July 1972 to the end of 1975 all films were scrutinized retrospectively by one of the authors and were included in the material if segmental vasoconstriction was present The year 1973 was chosen for determining the relative frequency All patients who were examined under general anaesthesia (mainly children) were excluded from the material

Technique of angiography The examinations were performed under local anaesthesia using transfemoral catheterization Details of the procedures in different types of angiography are given in Table 1

An AOT film changer grids of ratio 8 1 a film focus distance of 100 cm and a nominal focal spot of 0 6 mm × 0 6 mm was used In placentography and pelvic angiography in patients with possible tumour the blood flow to the legs was occluded by the application of sphygmomanometer cuffs on the thighs

For altering the haemodynamics in the examined region either an infusion of bradykinin (ERIKSON 1973) was given or a sympathetic blockade applied by local anaesthesia of the sympathetic nerve by 20 ml plain Bupivacaine (Marcaine)

On the basis of the final clinical diagnosis the patients were divided into two groups (1) those with acute and (2) those without acute arterial occlusion (Table 2)

Table 1

Different techniques at angiography in various vascular regions G = grey R = red

Vascular region	Type of catheter	Contrast medium	Amount of contrast medium (ml)	Pressure (kPa)	Exposure frequency
Coeliac artery + superior mesenteric artery	Ödman–Ledin (G)	Angiografin	30	295	3/s in 3 s 1/2 s in 16 s
Renal artery	Ödman–Ledin (G or R)	Angiografin	10–12	295	1/s in 3 s 1/2 s in 8 s
Lumbar aortography	Ödman–Ledin (G)	Urografin (45)	40	490	2/s in 4 s
Femoral angiography	Ödman–Ledin (G)	Angiografin or Urografin (45)	40–50	490	1–2/s in 5 s
Brachial artery	Cook head hunter	Angiografin or Urografin (45)	25–30	[illegible]95	1–2/s

Table 2

Distribution of the patients with segmental vasoconstriction according to clinical symptoms or diagnoses and survey of the vascular regions in which the constriction occurred Acute arterial occlusion (group 1) and without acute occlusion (group 2) Figures within parentheses refer to the number of patients

	Symptom or diagnosis	Arteries with segmental vasoconstriction
Group 1 (9 cases)	Placenta praevia (5)	Ext iliac artery
	Pelvic tumour (1)	Ext iliac artery
	Burn (2)	Ulnar artery (1) ulnar and interosseous arteries (1)
	Embolism of right ant tibial artery (1)	Left ant tibial artery
Group 2 (46 cases)	Intermittent claudication (8)	Arteries of healthy leg (7) affected leg (1)
	Peripheral ulcers (6)	—
	Abdominal pain ([illegible])	Hepatic artery (1) sup mesenteric artery (1)
	Pain in extremities (5)	Ulnar artery (1) arteries of leg (4)
	Symptoms from previous tibial fracture (3)	Arteries of lower leg
	Renal failure (4)	Scribner shunt (2) renal artery (1) ext iliac artery (1)
	Hypertension (9)	Sup mesenteric artery (6) renal artery ([illegible]) ext iliac artery (1)
	Others (9)	—
Case reports [illegible] to 6		
Case report 1		
Various diagnosis insulinoma Hodgkin s disease lymphangioma arteriovenous fistula etc		

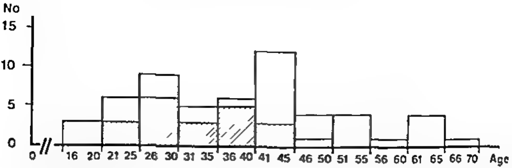

Fig 2 Age and sex distribution in the series of segmental vasoconstriction 1967 to 1975 Cross hatched columns females Unfilled columns males

This division was made because previously the phenomenon was suggested to be induced by acute arterial occlusion (THEANDER LEHRER)

Results

Twelve of the 67 patients had total cerebral infarction and have been reported in a separate publication (LÖRELIUS 1976) Excluding these 12 the material consisted of 55 patients the age and sex distribution appear in Fig 2 Segmental vasoconstriction was noted in 103 arteries (visceral arteries 21 pelvic and peripheral arteries 82)

During 1973 the relative frequency of patients with segmental vasoconstriction was 4 2 per cent (16 of 381 patients) In the group of patients below 50 years of age (n = 120) 14 had segmental vasoconstriction i e 11 7 per cent (Fig 3)

The distribution of clinical diagnoses in groups 1 and 2 is given in Table 2 which also demonstrates the blood vessels in which segmental vasoconstriction was observed

Some cases of special interest are presented below

Case 1 A male who has smoked cigarettes since the age of 13 years started to have pain in the left leg at 14 years and progressive muscular atrophy developed in the left thigh Extensive neurologic and neuroradiologic investigations revealed nothing abnormal Angiography of the lower extremities following puncture of the left femoral artery was performed at 15 years Segmental vasoconstriction was found in the right external iliac and superficial femoral arteries A local spasm was observed around the catheter on the left side but no organic abnormalities were demonstrated At the age of 19 years sacral exploration from the anterior approach was undertaken for a suggested neurinoma or conus tumour Extremely narrow iliac arteries were found at the operation but no tumour Angiography was again performed to exclude organic vascular pathology this time following puncture of the right femoral artery A local spasm occurred around the catheter on the right side and segmental vasoconstriction in the left external iliac and superficial femoral arteries The patient continued to have symptoms and was therefore admitted at age 20 for lumbar sympathectomy *Preoperative* angiography again revealed segmental vasoconstriction in both external iliac arteries On the following day angiography was performed after left sided lumbar sympathetic blockade This examination showed in the left leg a shorter circulation time and slightly less evident

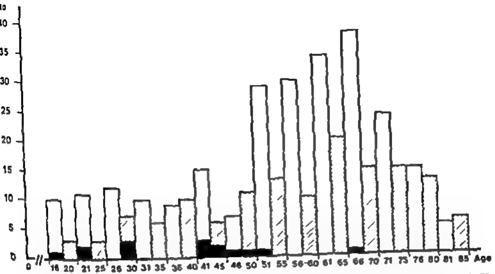

Fig 3 Age and sex distribution in the series of abdominal and peripheral angiographies in 1973 Patients with segmental vasoconstriction are marked with black Cross hatched columns females. Unfilled columns males

vasoconstriction in the external iliac artery but marked segmental vasoconstriction in the deep femoral artery The patient was free from pain in the left leg after the sympathetic blockade and sympathectomy was performed with a primarily good result However the pain has returned in the same leg but is still not as severe as preoperatively

Case 2 A male who has smoked cigarettes since the age of 19 years developed skin lesions on the finger tips and coldness of the hands when he was 49 years old At angiography of the left arm only sparse fill ng of the digital arteries was obtained At first the skin lesions were treated locally but subsequently two distal phalanges were amputated At the age of 54 years the patient also complained of cold feet Plethysmography revealed low resting flows in the legs especially on the left side Angiography of the lower extremities showed bilateral segmental vasoconstriction in the popliteal artery but no occlusion The flow rate of the contrast medium was considered rather slow Angiography of the left arm revealed segmental vasoconstriction in the brachial artery and occlusion of the palmar arch and interdigital arteries After stellate blockade the segmental vasoconstriction disappeared and the propagation time of the contrast medium was shortened by 11 seconds counted from the same point on the brachial artery to the wrist The clinical diagnosis is Buerger s disease and this is supported by microscopy of the arteries of the amputated phalanges

Case 3 A male who has smoked f r many years presented with intermittent claudication in the right leg at the age of 37 At 39 ye rs an ulcer developed on the right foot Angiography revealed occlusion of the superficial fe noral artery Sympathectomy was performed and the ulcer healed but the intermittent claud cation symptoms persisted Angiography of the legs at 40 years demonstrated occlusion of the superficial femoral artery and segmental vasoconstriction proximal to the occlusion After infusion of bradykinin the vasoconstriction disappeared Thrombo-endarterectomy was performed. Six months postoperatively an occlusion was demonstrated in the operation area On microscopy of the right superficial femoral

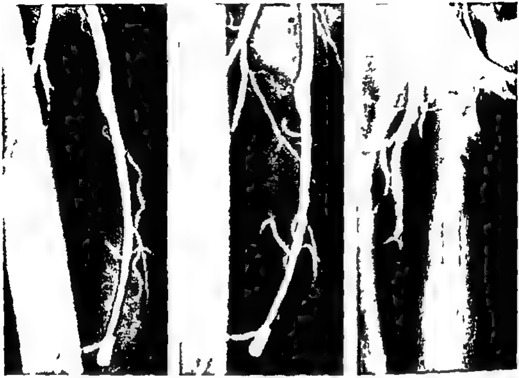

Fig 4 Case 3 Angiography at 40 years of age a) Segmental vasoconstriction in the right superficial femoral artery proximal to an occlusion b) After injection of bradykinin the vasoconstriction has disappeared c) At 42 years The right superficial femoral artery is now completel occluded at the level of the origin of the deep femoral artery

artery thickening of the media degenerative foci and small inflammatory infiltrates were found Repeat angiography at 42 years revelead occlusion of the superficial femoral artery within the region of the previous vasoconstriction Segmental vasoconstriction was now also observed in the left fibular artery The patient was readmitted at the age of 44 years with threatening gangrene in the left foot Angiography showed segmental vasoconstriction of the left popliteal and left anterior tibial arteries and occlusion of the fibular artery where segmental vasoconstriction had been noted two years previously Since that time the patient has been hospitalized almost continuously Attempts at curing his smoking habit have failed At 45 years the threat of gangrene of the left foot was even more marked Repeat angiography revealed total occlusion of the left superficial femoral artery in the adductor channel with collateral circulation as far as the anterior tibial artery A bypass operation between these two arteries was performed but the gangrene progressed and at 46 years of age the patient underwent below knee amputation on the left side In addition he has had repeated attacks of thrombophlebitis The clinical diagnosis is Buerger s disease (Figs 4 5)

Case 4 A female who has smoked since the age of 12 years complained of pain in the arch of the foot when walking at 15 years of age This pain developed into symptoms similar to intermittent claudication at a walking distance of 100 to 200 m When she was 16 years old she began to have episodes of migrating thrombophlebitis At 19 years of age refractory ulcers developed on the lower leg and a chronic ulcer on the left great toe Angiography

a b c

Fig. 6 Case 5 Segmental vasoconstriction in a) the right external iliac artery b) the right superficial and deep femoral arteries and c) the superior mesenteric artery

A gangrenous ulcer developed on the right great toe Angiography revealed segmental vasoconstriction of the right external iliac superficial femoral and anterior tibial arteries and occlusion of the right fibular artery and the posterior and anterior tibial arteries distal to the vasoconstriction Repeat angiography 3 months later revealed segmental vasoconstriction of the right external iliac artery both superficial femoral arteries and the right anterior and posterior tibial arteries Following lumbar sympathetic blockade the segmental vasoconstriction of the superficial femoral arteries disappeared The contrast flow in the foot did not improve because the contrast medium was shunted over to the venous side in the thigh and calf As the radial pulse was not palpable on either side angiography of the upper extremities was performed On neither side was the radial artery filled This was considered to represent an anatomic variant Segmental vasoconstriction was observed in the left ulnar artery it disappeared after infusion of bradykinin

The right great toe was amputated after which the patient was free from pain Clinical diagnosis Possibly Buerger s disease or systemic lupus erythematosus (Fig 7)

Discussion

Segmental vasoconstriction may appear temporarily in a vess l It now seems to be generally accepted that the phenomenon is caused by a change in arterial tone

Opinions have been divided concerning the frequency of this phenomenon It is therefore of interest that in the present series only 5 patients presenting the phenomenon had been noted in the report to the referring physician during the period January 1967 to July 1972 A considerably higher frequency was registered for the period August 1972 to December 1975 Thus either the frequency had increased or more probably is dependent upon the interest of the examiner in the phenomenon Among the patients below 50 years of age the frequency of segmental vasoconstric

Fig 7 Case 6 a) Segmental vasoconstriction in the left superficial and deep femoral arteries b) Following sympathetic blockade the vasoconstriction has disappeared c) Segmental vasoconstriction in the anterior tibial artery proximal to an occlusion at the level of the ankle d) Following sympathetic blockade the vasoconstriction in the anterior tibial artery remains e) Segmental vasoconstriction present in the left ulnar artery

tion was just over 10 per cent This is in good accordance with the frequency reported by ISCHIKAWA et coll (1973) who performed their examinations under spinal anaesthesia

In recent years it has been reported that segmental vasoconstriction occurs more often in certain patients e g in acute cardiac failure (SIEGELMAN et coll 1974) non occlusive intestinal ischaemia (WITTENBERG et coll 1973) and total cerebral infarction (LÖRELIUS 1976) Common to these groups of patients is that the vasoconstriction has been observed in the mesenteric artery and that the patients have been in a stage of circulatory failure In these patients therefore the vasoconstriction may possibly be regarded as an expression of a reaction induced by the low systemic blood pressure Other investigators also emphasize the importance of the mesenteric artery for the blood pressure regulation (BYROM 1954 GIESE 1964 GOLDBY & BEILIN 1972) It is of interest that among 9 patients with hypertension in the present series segmental vasoconstriction was observed in the superior mesenteric artery in 4 cases and in both the superior mesenteric and renal arteries in one further case

NOCHY (1973) has reported segmental vasoconstriction in a high frequency among patients with vascular nephropathy in acute renal insufficiency He found segmental vasoconstriction of the superior mesenteric artery in 8 patients and in the renal artery in a further 2 patients of the total 17 who were examined Nine of these 10 patients with segmental vasoconstriction also had arterial hypertension On the basis of these

cases HELENON (1975) relates the occurrence of segmental vasoconstriction as a sign of hypertension caused by increased renin release No determinations of the plasma renin were made but the authors state that the condition is usually characterized by an increase in renin hormone activity

Of the present patients with renal failure 2 had Scribner shunts which gave reason for performing the angiography A third patient underwent angiography after a kidney transplantation complicated by occlusion of the renal artery The fourth patient had bilateral kidney shock following a traffic accident These patients did not have hypertension at the time of the examinations

Segmental vasoconstriction has previously been reported to appear in arteries proximal to an occlusion which has led to discussion whether it may constitute a resonance phenomenon—a standing wave In the present series it was also observed proximal to an occlusion mainly when the occlusion was produced by the examiner for example by application of a sphygmomanometer cuff on the thigh In these cases the vasoconstriction may be regarded as a physiologic response to the trauma induced either by the local pressure on the artery or secondary to the anoxia in the leg This mechanism may explain the segmental vasoconstriction in the relatively small group 1 but not in the dominating group 2

Among patients with intermittent claudication segmental vasoconstriction occurred in the unaffected leg in 7 cases out of 8 A possible explanation for this is that blood flow is directed from the healthy leg to the anoxic leg with arterial occlusion Another more acceptable possibility is that the patient is predisposed to vasoconstriction and that this is more easily observed in relatively healthy arteries It is worthy of note that only one in this series of patients had Raynaud s disease

The possible prognostic importance of the segmental vasoconstriction is of considerable interest

The patients whose case histories are described all started smoking at an early age They are all relatively young and with nutritional disturbances in the extremities—in one case in the form of muscular atrophy in the left leg and in 5 cases in the form of ulcers or gangrene refractory to treatment With the exception of case 4 vasoconstriction was noted at repeated examinations and in several arteries In case 3 occlusion was observed on 3 occasions in an artery which had previously demonstrated segmental constriction In these patients it is conceivable that the vasoconstriction may have caused a nutritional injury to the arterial wall This in turn might have led to wall abnormalities causing a reduced flow in the artery which would predispose to occlusion A corresponding line of reasoning may be held for the group of patients with intermittent claudication

The reason that arteries may exhibit segmental constriction is not clear A mechanical cause is conceivable in some cases e g the presence of a catheter or a needle against the arterial wall or compression of the artery This does not explain vasoconstriction that occurs far from the catheter or far from an occlusion The contrast medium may have an irritating effect However in most cases the contrast medium has a slight

vasodilative effect and furthermore vasoconstriction occurs in a relatively small number of patients Therefore *it would seem most probable that segmental vasoconstriction is an expression of some form of hyperirritability of the arteries* That segmental vasoconstriction may result from administration of hypertensin for example has been demonstrated by GIESE (1964) and GOLDBY & BEILIN (1972) Thus a humoral induction could be considered as one possible mechanism

Electric stimulation of the sympathetic innervation of the renal artery in rabbits produced segmental vasoconstriction of the vessel (BERGQUIST et coll 1971) A neurogenic mechanism thus seems probable Supporting this view is the fact that there have been no reports of segmental vasoconstriction in examinations under general anaesthesia Preliminary results of recordings of sympathetic nerve activity of skin nerves in man have shown that it is inhibited on induction of general anaesthesia (WALLIN) This may explain why segmental vasoconstriction has not been reported at angiographies in children as these examinations are performed under general anaesthesia

It is probable that all these pathogenetic factors cooperate and it seems reasonable *to believe that some people have a lower threshold for induction of vasoconstriction* than others a predisposition which may be congenital or acquired The threshold may possibly also be affected by smoking in certain individuals All 6 patients described were heavy smokers *Five of them have a certain or highly possible Buerger s disease* and it seems conceivable that this disease may initially be manifested as arterial segmental vasoconstriction Furthermore in patients with Buerger s disease a corresponding phenomenon may also occur on the venous side which could explain the recurrent migrating thrombophlebitis—a part of this disease

SUMMARY

Frequency and pathogenetic factors involved in arterial segmental vasoconstriction observed in a series of 55 patients are analyzed A large number presented peripheral nutritional disturbance and these included 5 patients with definite or highly possible Buerger s disease The possibility that in certain patients segmental vasoconstriction may be an early sign of systemic or local arterial disease is discussed

ZUSAMMENFASSUNG

Die Häufigkeit und die pathogenetischen Faktoren die an der arteriellen segmentellen Vasokonstriktion beteiligt sind wurden bei einer Serie von 55 Patienten analysiert Eine grosse Anzahl zeigte periphere nutritive Storungen und diese umfasste 5 Patienten mit einer definitiven oder sehr wahrscheinlichen Buergerschen Erkrankung Es wird die Moglichkeit diskutiert dass bei bestimmten Patienten die segmentelle Vasokonstriktion ein Frühzeichen einer System Erkrankung oder einer lokalen arteriellen Erkrankung ist

RESUMÉ

Les auteurs étudient la fréquence et les facteurs pathogeniques de la vasoconstriction segmentaire artérielle observes sur une série de 55 malades Un grand nombre de

5

presentaient des troubles nutritionnels périphériques parmi lesquels 5 malades avaient de façon certaine ou de façon très probable une maladie de Buerger Les auteurs discutent la possibilité que chez certains malades une vasoconstriction segmentaire puisse etre un signe précoce de maladie artérielle systémique ou locale

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EVALUATION OF A MODIFIED METHOD FOR ARTHROGRAPHY OF THE KNEE

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Arthrographic methods may be divided into two main groups: the methods employing a positive contrast medium only (LINDBLOM 1948) and those using a positive medium combined with gas (BIRCHER 1931, VAN DE BERGH & CRÈVECOEUR 1953). Both methods have been combined with fluoroscopy (TURNER & BUDIN 1970) or with fluoroscopy and axial loading of the leg (ZAKRISSON 1960). Tomography has also been used in connection with arthrography (FAGERBERG 1956). Both vertical and horizontal beam directions have been used, the latter technique by ANDRÉN & WELIN (1960) and MITTLER et coll. (1972). The fact that so many different methods have been tried may indicate that the ideal technique has not yet been found, despite the great clinical advantages to be gained from an accurately performed examination. A correct diagnosis of meniscus injuries in more than 95 per cent of the patients has been obtained in some series (KESSLER et coll. 1961, NICHOLAS et coll. 1970). The various radiographic methods have been evaluated by comparison with the surgical findings. Several authors stress the importance of being familiar with the method used. In an arthrographic series of 311 meniscus injuries MCBEATH & WIRKA (1972) found 94.7 per cent of the diagnoses to be correct, but the corresponding figure for cruciate ligament injuries was not given. A high percentage of correct diagnoses of meniscus injury with the aid of a double contrast technique was reported by NICHOLAS et coll., but of the injuries of the cruciate ligaments only 50 per cent we-

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detected However high reliability in the arthrographic diagnosis of this lesion has been reported by LILJEDAHL et coll (1965 1966) using a positive contrast medium

Method

A modified technique for arthrography based on the method described by LINDBLOM was introduced at this hospital in 1971 The modification consisted of fluoroscopy and forced varus and valgus positioning during the exposure The positioning was obtained by immobilizing the knee with a constant static force applied by means of slings around the leg and attached to the edge of the table Dodging was also employed (LEVEN 1974)

The modified technique has been applied in some 1 200 examinations none of which led to complications of these 419 were carried out on referral from the Department of Surgery and 132 were operated upon This group was selected for evaluation of the reliability of the arthrographic diagnosis The patients ages ranged from 14 to 63 years The original radiographic appearances of the medial and lateral menisci and the cruciate ligaments were compared with the observations at surgery The radiographic reports had been issued by one of four radiologists in charge of the patients from the Department of Surgery at the time The arthrotomy was performed by one of 7 surgeons

Results

Medial meniscus The surgical reports for 2 patients contained no data relating to the injury In a third case the operation was not performed until 2 years after arthrography which had not revealed any lesion The operation was carried out because of a possible lesion of the anterior cruciate ligament In a fourth case no radiographic evaluation of the medial meniscus was possible because of superimposition of an unusually large Baker s cyst These 4 patients were excluded from the comparison

In the 2 cases (Table 1) where injury to the medial meniscus was found at the operation but where arthrography disclosed no abnormality a review of the films revealed no lesion either In 8 patients the films demonstrated injuries not found on arthrotomy In 3 the meniscus had been operated upon previously and the injuries to the residual portion present on arthrography were estimated to be of no clinical significance the meniscus was consequently not removed In 4 the main reason for arthrotomy was injury to the cruciate ligaments and since there was no demonstrable or palpable abnormality of the meniscus it was left in position In the eighth case the meniscus was extirpated and microscopy of the specimen failed to disclose any injury

There is a risk that meniscus lesions may be overlooked at operation particularly in the case of horizontal ruptures within the substance caused by degeneration (SMILLIE 1951) Deposits of contrast medium in the actual substance of the meniscus observed in more than one projection should be assigned high pathologic significance

Table 1

Medial meniscus

Radiography	Arthrotomy	
	Normal	Lesion
Lesion	8	95
Normal	23	2

Table 2

Lateral meniscus

Radiography	Arthrotomy	
	Normal	Lesion
Lesion	[illegible]	14
Normal	103	8

Table 3

Anterior cruciate ligament

Radiography	Arthrotomy	
	Normal	Lesion
Lesion	3	33
Normal	85	10

even if the meniscus is normal in its external appearance at arthrotomy There is reason to suppose that forced valgus positioning employed during the arthrography promotes the filling of small cavities in the meniscus with the medium

As regards the medial meniscus the reliability of the various techniques for arthrography varies but little The medial meniscus is readily accessible on arthrography being rarely concealed by other structures Normally it is attached to the collateral ligament and the joint capsule over its whole length it follows that the presence of contrast medium medial to the meniscus invariably is of pathologic significance

Lateral meniscus The surgical report of one patient gave no information on the state of the lateral meniscus and this case was excluded The results of the comparison are given in Table 2

In 8 patients where lesions of the lateral meniscus were found on arthrotomy but had not been mentioned at radiography no definite evidence of injury was found on a review of the films This failure in arthrographic diagnosis may have been due

to the difficulty of projecting all aspects of the meniscus without superimposition by other structures especially the sheath of the popliteal tendon and the bursae of the popliteal fossa Moreover the fact that the capsule is attached only at its anterior margin to the meniscus makes it difficult if not impossible to establish a reliable arthrographic diagnosis of partial detachment of the meniscus

In the 6 patients in whom there was evidence of a lesion of the meniscus on arthrography but not at arthrotomy the meniscus was left intact At a review of the films lesion was beyond doubt The discrepancy between the findings at arthrography and arthrotomy is probably due to the difficulty of inspecting the lateral meniscus at operation a rupture of the meniscus is not always visible on its surface the contrast medium may enter the rupture from the lateral (peripheral) aspect or from below In these cases radiography is likely to be more reliable than both inspection and palpation at arthrotomy In the 6 cases under discussion the fact that at arthrotomy the surgeon found other pathologic states within the joint such as rupture of the crucial ligaments which was considered the most important lesion to repair may have had some significance

When injury to the lateral meniscus is clinically suggested the reliability of the arthrographic diagnosis can be augmented by increasing the number of projections and possibly by using a primary magnification technique The highest reliability of arthrographic diagnosis in injuries of the lateral meniscus is probably achieved by using the technique described by ANDRÉN & WELIN With the use of horizontal beam direction superimpositioning is reduced to a minimum This explains the excellent results with this method as regards the lateral meniscus reported by NICHOLAS et coll and others

Anterior cruciate ligament In all the arthrotomies the cruciate ligaments were inspected thoroughly during traction on the knee The radiographic diagnosis of anterior cruciate ligament lesions is based on the demonstration of excessive sagittal instability of the joint and a defective margin of the ligament in the lateral projection during anterior traction of the lower leg The results of the comparison are presented in Table 3

In none of the patients was there any associated injury of the bone In the 10 patients where an injury to the ligament was found at arthrotomy but not reported a review of the films showed that the amount of contrast medium present at the anterior part of the ligament was inadequate for diagnosis In one of the 3 patients in whom an injury of the anterior cruciate ligament was reported Hoffa s fat pad was found to be adherent to the ligament thereby rendering its margin hard to delineate on the film

Contradictory information on the state of the anterior cruciate ligament in one patient was present at surgery At arthrotomy the ligament was estimated to be normal but subsequent arthroscopy disclosed evidence of injury of the ligament This patient was not included in the case material

Conclusions

The modified technique for arthrography of the knee described by LEVEN has a high degree of reliability regarding diagnosis of lesions of the medial meniscus This is also the case with several other techniques but the modified one offers some advantages that facilitate the diagnosis Evaluation of the lateral meniscus is some what more difficult with this method as with several others An exception is the method described by ANDREN & WELIN They encountered only 1 case of missed arthrographic diagnosis in a material of 12 cases with evident injury of the lateral meniscus at arthrotomy Using their technique NICHOLAS et coll encountered a correct arthrographic diagnosis in 93 per cent in a material of 57 injured lateral menisci The value of horizontal beam direction and the use of double contrast is obvious superimpositioning is avoided and the diagnosis is facilitated However the double contrast method is less reliable for demonstration of lesions of the cruciate ligament in the material of NICHOLAS et coll 19 lesions of crucial ligaments were found at arthrography as against 42 encountered at operation The present method is obviously more reliable for diagnosis of cruciate ligament lesions It is based on the concept that the positive contrast medium will mix with the synovial fluid (LINDBLOM) and thus reach all spaces inside the joint The method described by ANDREN & WELIN is aimed at preventing intermixture between contrast medium and synovial fluid as with other double contrast techniques Such methods are thus preferable for examination of the menisci rather than of the entire joint

SUMMARY

A modified method for knee arthrography based on the technique introduced by LINDBLOM has been applied in 1 200 patients The arthrographic reports on 132 patients submitted to arthrotomy are compared with the findings at surgery The modified technique is easy to perform and offers a fairly reliable all round method for diagnosis of both meniscus and crucial ligament lesions

ZUSAMMENFASSUNG

Eine modifizierte Methode zur Arthrographie des Knies die sich auf der von LINDBLOM eingeführten Technik basiert wurde an 1 200 Patienten angewendet Arthrotomie wurde bei 132 Patienten vorgenommen und die arthrographischen Ergebnisse mit den operativen Befunden verglichen Die modifizierte Technik ist leicht durchzuführen und bietet eine ziemlich zuverlässige Methode zur Diagnose von Meniscus- und Kreuzband Schaden

RESUME

Une methode modifiee d arthrographie du genou basee sur la technique mise au point par LINDBLOM a ete appliquee à 1 200 malades Les comptes rendus d arthrographie de 132

malades ayant subi une arthrotomie ont été comparés aux constatations opératoires Cette technique modifiée est d exécution facile et constitue une méthode d examen global assez fidèle pour le diagnostic des lesions des ménisques et des ligaments croises

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ORTHOPANTOMOGRAPHY OF THE MANDIBLE

H ESBERG and M HAVERLING

Conventional radiography of the mandible ordinarily implies exposures in several projections due to its curved anatomy Orthopantomography simplifies the examination allowing the mandible to be adequately demonstrated in one single film supplemented if necessary with one or two additional films and at a low dose rate However the mental region is not as well outlined as the other parts of the mandible At times this region is rather defectively demonstrated in spite of meticulous care being taken in positioning of the head However it has been found that exposure of the mandible with the head deviating about 25 degrees from the sagittal plane demonstrates the mental region to full satisfaction The value of this additional view will be exemplified by two patients selected from a series of cases

Case reports

Case 1 A woman aged 55 with a squamous cell carcinoma of the gingiva and destruction of the adjacent left part of the mental region including the margin of the mandible underwent radiation therapy Postirradiation orthopantomography in the conventional a p projection failed to demonstrate the details of the destruction (Fig 1 a) In the oblique projection the lesion was well defined throughout (Fig 1 b)

Case 2 A male aged 62 with a cyst in the left upper jaw and a large multicystic lesion in the left anterior part of the mandible The right aspect of the mandibular lesion was well delineated on an oblique view only (Fig 2)

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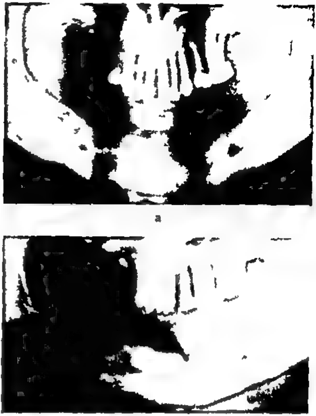
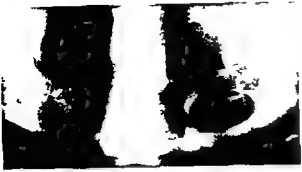


Fig 1 Case 1 a) Orthopantomography Conventional straight a p projection Destruction to the left of the anterior margin Details of the marginal area of the lesion are not appreciated satisfactorily b) The head deviated about 25 to the left Marginal area of destruction is well demonstrated

Discussion

On conventional examination of the mandible it is difficult to demonstrate the anterior region satisfactorily In the a p projection the cervical spine is superimposed rendering the details of the mandible hard to appreciate Oblique projections result in foreshortened views of this area and overlap of contiguous parts On intraoral films only the marginal part of the anterior region is well demonstrated

Standard orthopantomography generally is sufficient for the examination of lesions not involving the mental region of the mandible A prerequisite is that the head is held in a straight a p projection which will provide for symmetric demonstration of the mandible The reason for the lower quality of the image of the mental region is that the positioning space allowed for ample demonstration of this area is much narrower than for other parts of the mandible Thus technical factors inherent in the system of orthopantomography makes the anterior region a critical one (PAATERO 1954) By deviating the head about 25 degrees from the sagittal plane the deficiency in definition of the anterior region is readily overcome (Figs 1 b 2 b)



a

b

Fig 2 Case 2 a) Orthopantomography Conventional straight a p projection Polycystic lesion in the left anterior part of the mandible Polycystic lesion in the left anterior part of the mandible Right part of the lesion not clearly demonstrated b) The head deviated about 25 to the left Details of the right part of the lesion well outlined

SUMMARY

With orthopantomography the anterior region of the mandible is usually not as well demonstrated as the lateral parts A supplem ntary view with the mandible deviating about 25 degrees from the sagittal plane is ideal for satisfactory demonstration of its anterior part

ZUSAMMENFASSUNG

Mit der Orthopantomographie lasst sich die vordere Region des Unterkiefers gewohnlicherweise nicht so gut darstellen wie die seitlichen Teile Ein zusatzliches Bild mit dem Unt rkeifer um etwa 25 Grad vom Sagittalplan rotiert ist ideal um den vorderen Teil zu friedenstellend darzustellen

RESUME

L orthopantomographie ne montre habituellement pas aussi bien la region anterieure de la mandibule que les parties laterales Une vue complementaire prise quand la mandibule est tournee d environ 25 par rapport au plan sagittal est ideale pour une mise en evidence satisfaisante de la partie antérieure

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CHRONIC SCLEROSING OSTEOMYELITIS OF THE MANDIBLE

Radiographic differential diagnosis from fibrous dysplasia

ANDREAS JOHANNSEN

Fibro-osseous dysplasia and chronic osteomyelitis of the mandible may resemble each other so closely, especially in the clinical manifestations but sometimes radiologically and histologically as well, that considerable difficulty may be encountered with the differential diagnosis. Little mention has been made of this problem in the literature, but it has been discussed by FITZPATRICK (1966) and LAUTENBACH & DOCKHORN (1968) among others. That the problem is greater than suggested in the literature is clear from the fact that SCHAMAN et coll. (1970) among 35 patients with benign fibro-osseous lesions of the mandible and maxilla found 6 cases of chronic osteomyelitis (5 in the mandible and 1 in the maxilla) in all of which the condition primarily had been incorrectly considered as fibrous dysplasia at both the clinical and the radiographic examinations, and in 5 of them at microscopy as well.

On the basis of a material confirmed by microscopy an attempt has been made to identify radiologic appearances which are typical of chronic osteomyelitis of the mandible and which could be used to differentiate this condition from fibrous dysplasia.

Material. This consisted of 8 patients with a primary radiographic diagnosis of chronic mandibular osteomyelitis (group I) and 5 patients with an uncertain radiographic diagnosis of chronic mandibular osteomyelitis or fibrous dysplasia of the

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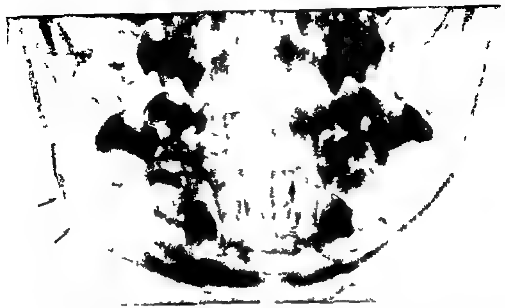

Fig 1 Chronic sclerosing osteomyelitis Enlargement and mild sclerosis of right half of lower jaw Periosteal reaction at the site of the biopsy (→)

jaw (group 2) All the microscopic preparations from the lower jaw in these 13 patients (groups 1 and 2) were carefully re examined

In addition 5 patients with a diagnosis of fibrous dysplasia of the mandible were included in the material (group 3)

P a and oblique lateral projections of the lower jaw were obtained in all cases as well as orthopantomographic views of the lower jaw in most cases and tomographic views in a few of them In 2 patients with an uncertain diagnosis films from long bones were also obtained with a view to establishing possible dysplastic foci outside of the mandible

The patients recorded as having chronic osteomyelitis were under observation for 4 to 10 years while those in the dysplasia group in most instances were examined on one or a few occasions only

Results

In the retrospective analysis of the biopsies from the 13 patients with a conclusive or an uncertain diagnosis of chronic osteomyelitis consideration was paid to the criteria for the differential diagnosis between chronic osteomyelitis and fibrous dysplasia of the jaw mentioned by SCHAMAN et coll (1970) and ADLER & HARLE (1974) All the preparations considered to show chronic osteomyelitis displayed inflammatory foci with reactive new bone formation often interspersed with sclerosis and sometimes with small bone sequestra None of them had the appearance characteristic of fibrous dysplasia namely that of a fibrous stroma component and bone meta

Table

Five patients with an uncertain primary diagnosis all classified at a microscopic revision as chronic osteomyelitis

	Year	Symptoms	Roentgen diagnosis	Microscopic diagnosis	Clinical diagnosis	Treatment
3 year old boy Fig 1	1966	Swelling, tenderness	Ewing s sarcoma? Chronic osteomyelitis?	Osteitis	Osteitis	Antibiotics
	1966	Increased swelling, pain	Fibrous dysplasia	Osteitis fibrous dysplasia?	Fibrous dysplasia	
	1971	Further swelling, pain	Chronic osteomyelitis	Osteitis	Chronic osteomyelitis	Operation
	1971 1975	Condition unchanged	Chronic osteomyelitis	Osteitis	Chronic osteomyelitis	Operation antibiotics
11 year old boy Fig [illegible]	1969				Parotitis 2	Antibiotics
	1971	Pain swelling	Ewing s sarcoma? Chronic osteomyelitis? Fibrous dysplasia?	Osteitis	Fibrous dysplasia	
	1971	Increased swelling, intermittent pain	Fibrous dysplasia	Fibrous dysplasia	Fibrous dysplasia	
	1971 1975	Condition unchanged	Fibrous dysplasia		Fibrous dysplasia	
1[illegible] year old girl Fig 3	1964	Indolent swelling	Cyst	Dermoid cyst	Dermoid cyst	Operation
	1966	Intermittent swelling and pain	Chronic osteomyelitis? Fibrous dysplasia?	Osteitis? Fibrous dysplasia?	Fibrous dysplasia	Operation
	1969	Condition unchanged	Chronic osteomyelitis	Chronic osteomyelitis Fibrous dysplasia	Fibrous dysplasia	Operation
26-year old woman	1967	Pain swelling				Extraction antibiotics
	1968	Pain	Osteitis root remains		Osteitis	Operation antibiotics
	1969	Intermittent swelling and pain	Osteitis	Osteitis Fibrous dysplasia	Fibrous dysplasia	Operation
	19"0	Condition unchanged	Osteitis Fibrous dysplasia?		Fibrous dysplasia	

Table (*cont.*)

	Year	Symptoms	Roentgen diagnosis	Microscopic diagnosis	Clinical diagnosis	Treatment
	1971–1975	Condition unchanged	Chronic osteomyelitis?	Osteitis	Chronic osteomyelitis?	Operation several times
44-year old woman	1969					Extraction
	1970	Intermittent swelling and pain	Fibrous dysplasia	Fibrous dysplasia?	Fibrous dysplasia	
	1971	Condition unchanged	Chronic osteomyelitis?	Chronic osteomyelitis	Chronic osteomyelitis	Operation
	1974	Condition unchanged	Chronic osteomyelitis	Chronic osteomyelitis	Chronic osteomyelitis	Operation

plasia fairly uniformly distributed and extending all over the affected area in the bone, with bone formation usually without an osteoblastic covering (MYHRE JENSEN 1976).

The microscopic revision thus confirmed the diagnosis in group 1.

The patients diagnosed at radiography as having fibrous dysplasia (group 3) had the typical clinical and radiologic appearances of this condition. A microscopic confirmation of the diagnosis was not available in any of these cases.

The 5 patients with an uncertain primary diagnosis (group 2) were all classified at the microscopic revision as cases of chronic osteomyelitis. In all of these patients both the clinical and the radiologic findings and in several instances the microscopic appearances as well were atypical of chronic osteomyelitis. Three of the patients had been primarily considered as having chronic osteomyelitis, while the other 2 were diagnosed and treated as cases of dysplasia, one of them however only after repeated treatments for chronic osteomyelitis with a negative result (Table).

Discussion

Mandibular osteomyelitis usually arises through the spreading of an odontogenic or a traumatogenic infection and manifests itself as a rule as moderate swelling, redness and tenderness in the involved region, sometimes complicated by development of fistulas, secretion of pus and formation of sequestra (TRAUNER 1964, ASKITIS 1972). It is usually possible to cure the disease in the acute stage with complete inhibition of the process through the use of antibiotics, possibly supplemented with a surgical intervention. In some cases however the process develops into a chronic phase strongly resistant to treatment and characterized by periodical swelling and

a

b

Fig. 2. a) Chronic sclerosing osteomyelitis. Enlargement and irregular bone structure with sclerosis and rarefactions on right side of lower jaw. No signs of a periosteal reaction. b) 1 year later. P.a. projection. Increasing enlargement and sclerosis.

pain in the involved region, sometimes associated with a temperature elevation. The symptoms often disappear spontaneously (STAPHNE 1969).

Since the introduction of antibiotics, a change has taken place in the situation with respect to osteomyelitis of the jaws (TRAUNER), the disease now often manifesting itself with atypical signs and symptoms, with the result that many cases risk being wrongly diagnosed and wrongly treated (ROWE & HESLOP 1957). This happened with 2 of the present patients, who were first diagnosed and treated as cases of fibrous dysplasia, while in the other 3 patients considerable differential diagnostic difficulties were encountered in distinguishing the condition from fibrous dysplasia. Such difficulties seem to have become more marked in recent years, and this may have some connection with the alteration that has occurred in the syndrome of chronic osteomyelitis.

Mandibular fibrous dysplasia manifests itself, according to LAUTENBACH & DOCKHORN, in two clinical forms. One of these displays a continuously symptom-free course with gradually increasing osseous enlargement of one half of the lower jaw, while in the other form the course is intermittent, with periods of increasing swelling, pain and tenderness on one side of the lower jaw, possibly accompanied by swelling of regional glands and a temperature elevation.

All the cases in the table which were classified at the microscopic revision as chronic osteomyelitis were characterized clinically by a *protracted course with*

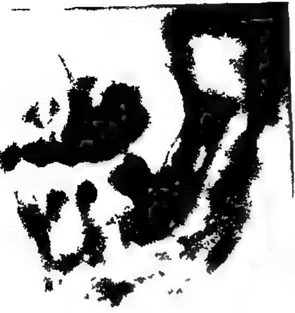

Fig 3 Zonography Slight perios steal new bone formation along the base of the mandible and several large sharply delimited rarefied areas with irregular outlines

periods of pain and increasing swelling of one half of the mandible In no case had there been any acute phase with redness or hotness in the region nor was there any record of pus secretion fistula formation or a temperature elevation In those cases in which cultures were made from the bones no bacterial growth was obtained

The signs and symptoms in these cases thus considerably resembled the inter mittent form of fibrous dysplasia

Radiologically the appearances characteristic of chronic osteomyelitis consist of an increasing often irregular and blurred area of sclerosis and scattered osteolytic areas both within the sclerosed region and in the surrounding bone In addition p riosteal new bone formation usually occurs which in some instances may involve marked often irregular thickening of the cortex (STAPHNE)

The radiologic app arances of fibrous dysplasia of the mandible are highly vari able and without pathognomonic changes (OBWEGESER et coll 1973) Two basic forms may be distinguished (1) the osteolytic form with one or several usually well defined polycyclic rarefactions in an otherwise normal bone and (2) the osteo-sclerotic form with uniform sclerosis often passing over smoothly into a normal bone structure Between these two basic forms transitional ones are seen the most common being a combination of irregularly outlined often confluent sclerotic areas of varying size and osteolytic areas in the bone usually sharply delimited and with irregular outlines (OBWEGESER et coll) An osseous enlargement of one half of the jaw is often observed and in a few cases resorption of teeth roots as well

Both diseases may thus produce appearances characterized by irregularly outlined

regions of sclerosis of varying severity combined with more or less sharply delimited osteolytic areas and irregular enlargement of the jaw

The enlargement in chronic osteomyelitis is due to a periosteal reactive new bone formation resulting from lifting of the periosteum In fibrous dysplasia on the other hand it is the result of an appositional bone formation on the outer side of the cortex as one of the elements in a remodelling of the bone which is taking place because of the arrosion of the inner side of the cortex caused by the lesion The cortex may be very thin as a result of the arrosion but it is usually intact (ZIMMERMAN et coll 1958) and areas of periosteal new formation do not occur (CHURCH 1958)

In all cases in group 1 there was distinct evidence of periosteal new bone formation

This was also seen in group 2 although there it was very scanty in some cases so inconsiderable that it could only be detected at tomography In one or two cases it had an appearance resembling onion peelings thereby causing difficulty in the differential diagnosis from Ewing s sarcoma Definite periosteal new bone formation was in all instances established following biopsy but it was considered to have been caused by the surgical intervention not by the infection

Both in group 1 and group 2 the appearances in the individual cases varied greatly with increasing osteolysis in some periods and increasing osteosclerosis in others These changes were observed both within the primarily pathologic area and in contiguous bone that had been normal at previous examinations Progressing osteolysis was seen as a rule in connection with flare ups of the clinical symptoms whereas the increasing sclerosis was observed during periods when the lesion was quiescent

In group 3 no periosteal new bone formation was seen nor were any variations in the bone structure established

These findings—variations in the osseous structure during the course of the disease and to a lesser extent periosteal new bone formation—thus seem to be typical features of chronic osteomyelitis

Regular radiologic repeat examinations (possibly supplemented with tomography) are therefore to be recommended if problems arise in the differential diagnosis between osteomyelitis and fibrous dysplasia of the jaw Such examinations are particularly important in all cases of fibrous dysplasia with periodical pain and swelling since this form of dysplasia is hard to distinguish clinically from chronic osteomyelitis with the result that some cases of the latter disease are likely to be incorrectly diagnosed as fibrous dysplasia This control is the more important because considerable difficulty in differentiating between the two diseases may also be encountered at microscopy (SCHAMAN et coll)

Acknowledgement

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SUMMARY

Among 13 patients with chronic osteomyelitis of the lower jaw clinical radiologic and histologic difficulties were encountered in 5 cases in the differential diagnosis from fibrous dysplasia The radiologic and in some measure the clinical and histologic features typical of the two diseases are described Variations in the bone structure during the course of the disease as well as periosteal new bone formation are characteristics of chronic osteomyelitis When problems are encountered in differentiating between fibrous dysplasia with periodical pain and swelling and osteomyelitis *repeated radiologic examinations are to be recommended*

ZUSAMMENFASSUNG

Bei 13 Patienten mit chronischer Osteomyelitis des Unterkiefers traten in 5 Fallen klinische radiologische und histologische Schwierigkeiten auf eine Differentialdiagnose zur fibrosen Dysplasie zu stellen Das typische rontgenologische und in gewissem Umfang das klinische und histologische Erscheinungsbild dieser beiden Erkrankungen werden beschrieben Veranderungen der Knochenstruktur im Verlauf der Erkrankung sowie die periostalen Neubildungen von Knochen sind charakteristisch fur die chronische Osteomyelitis Wenn *Probleme bei der Differenzierung zwischen der fibrosen Dysplasie mit periodischen Schmerzen* und Anschwellung und eine Osteomyelitis auftreten werden wiederholte rontgenologische Untersuchungen empfohlen

RESUME

Sur 13 malades atteints d osteomyelite chronique de la mandibule le diagnostic differentiel avec la dysplasie fibreuse a presenté dans 5 cas des difficultes cliniques radiologiques et histologiques L auteur decrit les caractères radiologiques et dans une certaine mesure les caractères cliniques et histologiques typiques de ces deux maladies Les variations dans la structure osseuse pendant l evolution de la maladie ainsi que la formation d os perioste sont caracteristiques de l *ostéomyelite chronique Quand le diagnostic différentiel entre la dysplasie* fibreuse avec douleur periodique et tuméfaction et l osteomyelite présente des problemes il est recommande de faire des examens radiologiques repétés

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XEROGRAPHIC TOMOGRAPHY

C G HELANDER S REICHMANN and K ÅSTRAND

In xeroradiography the roentgen film is replaced by a layer of amorphous selenium which is electrostatically charged. When roentgen photons are absorbed within this layer a local reduction of the charge takes place In this way the image relief within the radiation is transformed into a charge relief in the Xerox plate during the exposure The image is developed by means of electrostatically charged powder sprayed evenly over the selenium plate The powder image thus obtained is transferred onto a paper impregnated with plastic A negative as well as a positive image can be obtained by means of different modes of development In xeroradiography image components of high spatial frequency tend to be augmented while low spatial frequencies tend to disappear from the image (BOAG 1973 HARLE et coll 1975) The xeroradiographic image is much less affected by a given amount of secondary radiation than is the same image recorded in film and furthermore the Xerox medium displays a much greater exposure latitude (SCHERTEL et coll 1974 SELIN et coll 1975)

The present report presents an investigation of the properties of the Xerox medium in tomography special attention being paid to the specific tomographic errors of depiction In conventional tomographic procedures two types of depiction errors are

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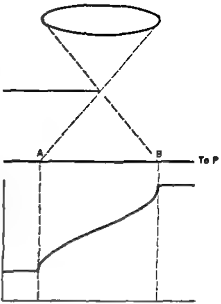

Fig 1 Circular tomography of a thin plate located above the tomographic plate (To P) The object is indicated by a horizontal line The tomographic movement path is seen in perspective at the upper end of the figure Two rays depicting the right end of the plate are indicated by interrupted lines these rays strike the tomographic plane at A and B Below the tomographic plane is indicated in a coordinate system how the different points of the tomographic plane are hit by different exposures The same exposure hits *the film plane The zone between A and B is the* partial attenuation zone and in the inner and outer limits of this zone rather steeply rising parts of the dose distribution curve appear These parts correspond to the spurious contours

encountered spurious contours and superimposition (REICHMANN 1972 a b ÅSTRAND & REICHMANN 1974) The main mechanism giving rise to spurious contours operates when an absorption boundary within the object is struck by tangential rays during a part of the exposure when the tomographic movement path is parallel to the absorption boundary in question

The so-called parasite lines in linear tomography represent a special case of such spurious contours Since they are all parallel with each other and with the tomographic movement path they are easy to identify When multidirectional tomographic movements are used the spurious contour are likewise multidirectional thus being much more difficult to identify since they may have any direction in the image Factors influencing the form and visibility of the spurious contours are the geometric properties of the movement path and the distribution of the exposure dose over different parts of this movement path

When an object situated outside the tomographic plane is tomographed a marginal zone appears in the resulting tomogram (Fig 1) Since it is due to the fact that the rays to a greater or lesser degree pass outside the object in question this marginal zone will be called the partial attenuation zone In the upper part of Fig 1—where the mechanism underlying the partial attenuation zone is demonstrated—a circular tomographic movement path is seen in perspective The tomographic plane is indicated by To P At a certain distance above this plane a thin plane object is situated both these planes being indicated only by straight lines Two rays are shown They strike the tomographic plane at the points A and B The projection of the object onto the tomographic plane in this way demonstrates not only its depiction in the

tomographic plane but in the film plane as well since the former plane has a constant prc ection onto the latter To the left of A a full attenuation zone is obtained all the radiation having passed through the object To the right of B all the radiation has passed outside the object and is thus unattenuated Between A and B the transition between the two radiation intensities occurs so that when moving from A to B an increasing amount of radiation having passed outside the object hits the tomographic plane The width of the partial attenuation zone increases when the tomographic angle is increased and when the distance between the object and the tomographic plane is increas d In the lower part of Fig 1 a distribution curve demonstrates how the radiation dose is distributed over the tomographic plane and thus over the film plane as well The dose distribution curve has steeply rising parts corresponding to the outer limits of the partial attenuation zone This steep rise in the curve corresponds to the visual impression of contours Since these contours have no informative character they are called spurious contours

If the tomographic movement path consists of several revolutions having dif ferent tomographic angles the number of spurious contours increases so that spurious contours are encountered within the partial attenuation zone and not only in its outer limits Thus if the movement path consists of three concentric circles six spurious contours will appear in the partial attenuation zone In the ideal state the partial attenuation zone contains no visible contours neither in its outer limits nor in the inner part of the zone This state corresponds to a perfect blurring (ÅSTRAND & REICHMANN 1974) In all tomographs which are commercially available today spurious contours are likely to be generated (REICHMANN 1972 a) The visi bility of these spurious contours gradually decreases when the distance between the object and the tomographic plane increases due to the signal/noise ratio becoming more and more unfavourable for visual detection The same applies if the distance is kept constant and the tomographic angle is increased Despite the fact that these geometric factors lead to a changed signal/noise ratio the visual impression of sharp ness in the spurious contours is always the same Thus the disappearance of a spurious contour is never caused by a contour becoming increasingly unsharp but is always the result of the contour in question having decreased in contrast to the limit of visibility (REICHMANN 1972 b)

In conventional tomography (linear circular ellipsoidal or hypocycloid) there is always a risk that spurious contours will appear in the tomogram deriving from structures outside the zone of real tomographic depiction For this risk to be eliminated a special spiral tomographic movement path has been constructed (ÅSTRAND & REICHMANN) consisting of ten revolutions in a certain geometric arrangement With this tomographic movement the risk of spurious contours arising is eliminated even for objects with a very high absorption difference in relation to its surroundings When this spiral movement path was constructed it was found that the distribution of the dose rate over the movement path was as important as the geometric properties of the path itself The construction of the form of the

spiral and its dose distribution were found to depend on several factors, one of these factors being the recording properties of the film. Screen film and non-screen film have generally different shapes as to their characteristic curves. The properties of the movement path had to be adapted to these different shapes in order to make for optimum blurring.

A second disturbance of tomographic depiction is superimposition, arising when a high absorbing structure is situated outside the tomographic plane. The structure may be blurred to such a degree as to be invisible in the final tomogram. Still the high absorption in this structure attenuates part of the whole radiation giving rise to the image and correspondingly leads to an underexposure of those parts of the tomographic plane that are depicted by rays passing through the structure. The harmful effect of superimposition has been carefully analysed in tomography of the mandibular joint by ECKERDAL (1973). ÅSTRAND & REICHMANN have shown that superimposition in radiography with screen film systems may be substantially reduced by using a high tube potential in combination with screens and films giving rise to exceptionally low noise levels.

The Xerox plates have a marked tendency towards so called contour enhancement. For this reason one might expect this recording medium to be unsuitable for tomography, since spurious contours might be expected to be more disturbing with this medium than with screen film combinations. However, with the recently constructed tomographic movement yielding perfect blurring in screen film tomography this difficulty could possibly be circumvented. Superimposition disturbances in screen film tomography are largely due to the limited exposure latitude of roentgen films. Since this latitude is much greater in Xerox plates, one might expect the harmful effects of superimposition to disappear more or less completely. Another reason for this expectation is the fact that Xerox radiography is usually performed at higher tube potentials than is film radiography.

Methods

The same principles were applied as were used in the optimisation of tomographic movements in screen film radiography by ÅSTRAND & REICHMANN (1974). In the present investigation with Xerox plates three different objects were used. The first was a slanted iron plate with a sharp edge. The test conditions resembled those of Fig. 1 apart from the fact that the plate was slanted against the tomographic plane. In this way the blurring of the sharp edge at different distances from the tomographic plane could be observed in one single image. The second object was a macerated femur with a drilled channel through the head and neck. The third object was a skull phantom embedded in plastic, where the ear and the mandibular joint were examined. Tomography was carried out with a Polytome. Spiral movements were simulated by means of concentric circle systems where the distance between two circles corresponded to the geometric properties of the spiral. These circular

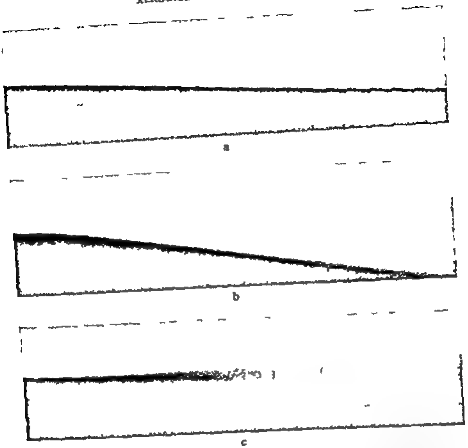

Fig 2 Xerographic tomograms of the edge of a slanting iron plate The plate is depicted dark The partial attenuation zone in (a) circular tomography 20 and (b) hypocycloid tomography 48 is limited by distinct contours Since the plate is slanted against the tomographic plane the partial attenuation zone becomes wider when the distance between the two planes increases In (c) 10-circle tomography 20 the partial attenuation zone is not limited by distinct spurious contours but appears as a dark band in its inner half and as a bright band in its outer half the latter band being difficult to discern in the reproduced image

movements were obtained by means of the zonography equipment which can give rise to circular movement paths having any tomographic angle between 0 to 25° By giving different doses to the different circles in the circle system a changing dose rate in the simulated spiral was imitated Nominal focus dimensions were 0 6 mm × 0 6 mm Three tomographic movements were compared namely circular (tomographic angle 20) hypocycloid (48) and a simulated optimised spiral of ten revolutions (20) Tomography of the iron plate was carried out at 110 kV tube potential with 1 4 mm additional Cu filtration The macerated femur was surrounded by air being tomographed at 75 kV with the same additional filter The skull phantom was tomographed at 120 kV without additional filtration Recording was made

Table

Relative geometry and dose distribution of the 10 circle system considered optimum in xerographic tomography

Radius	1 0	0 9	0 8	0 7	0 6	0 5	0 4	0 3	0 2	0 1
Dose	0 075	0 093	0 112	0 134	0 131	0 131	0 119	0 100	0 075	0 040

on Rank Xerox system 125 plates Before the exposure the plates were given the highest charge and development was arranged to give a positive image

Results

In circular tomography of the slanted iron plate the contour enhancement properties of the Xerox medium were found to operate in the recording of spurious contours in the same way as is usually seen for ordinary contours in a Xerox image With the development used a dark line was seen at the inner limit of the partial attenuation zone and a corresponding bright line occurred at the outer limit of the zone (Fig 2 a) In hypocycloid tomography of the same object the number of spurious contours was increased in accordance with the geometric properties of the movement path Also in this case contour enhancement occurred

Before multicircular tomography could be applied to the Xerox medium it had to be established how the dose distribution should be arranged in the circle system As mentioned in the introduction screen film and non screen film require somewhat different dose distributions in order to give optimum adaptation between radiation intensities and the characteristic curves The Xerox medium cannot be compared with these two types of film so that it could not be established theoretically which type if either of the two dose distributions used previously should be regarded as optimum In order to find out whether either of these principles for dose distribution could be utilised directly two tomograms were obtained by means of three concentric circles The dose distributions of these two circular systems were calculated to be optimum for screen film and non screen film respectively The geometric properties of the circle systems were identical The relative radii of the different circles were 1 0 0 6 and 0 2 respectively Thus six spurious contours were created within the partial attenuation zone the distance between two adjacent contours being constant In the resultant tomograms the three dark spurious contours in the inner half of the partial attenuation zone were inspected The intention was to find a dose distribution giving rise to three contours of equal visibility The dose distribution adapted for screen film tomography yielded three spurious contours which could not be distinguished by the naked eye to differ from each other in visibility This was considered acceptable and no further optimisation was carried out in this respect

In 10-circle tomography of the slanted iron plate the dose distribution adapted for screen film tomography (ÅSTRAND & REICHMANN) was used The geometry

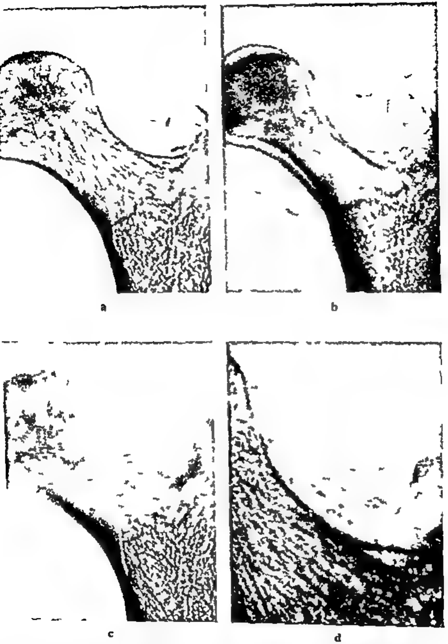

Fig 3 Tomography of a slanted macerated femur in air The tomographic plane passes through the object in the lower part of the images (a–c) In (a) circular and (b) hypocycloid tomography marked spurious contours and image deformation occur instead of the ideal unsharpness obtained in (c) 10-circle tomography *In (c) there* is a clear demarcation in the spongious bone indicating which parts of the object are blurred. This demarcation is absent in (a) and (b) In (d) part of the femoral neck in (a) appears in magnification A psuedo-image of spongious bone occurs both in the full attenuation zone and in the partial attenuation zone

a b

c

Fig 4 Ear tomograms of a macerated skull embedded in plastic In (a) circular tomography 20 a large number of disturbing spurious contours are seen making the tomogram useless for diagnostic purposes In (b) hypocycloid tomography 48 the contour contrast and the number of spurious contours are lower in accordance with the larger tomographic angle The mastoid process is sharply depicted in (a) and (b) owing to spurious contours (→) In (c) 10-circle tomography 20 spurious contours are absent The mastoid process is blurred

and dose distribution of this circle system appear in the Table A phenomenon referable to the contour enhancement effect of the Xerox medium was obtained (Fig 2 c) Thus in the inner half of the partial attenuation zone there was a diffuse darkening corresponding to the sum of the different spurious contours interfering with each other so that they were not visible as single contours but appeared together as an unsharp dark zone In the outer half of the partial attenuation zone a corresponding bright zone was seen Due to the unsharpness of this zone its reproduction is somewhat poor in Fig 2 c The result obtained was considered to be as good as possible and further testing on biologic objects was therefore carried out

The macerated femur was tomographed in a slanted position so that the tomographic plane passed through the lesser trochanter and through the most posterior part of the femoral head The neck of the femur was located in front of the tomographic plane When the circular tomographic movement was used (Fig 3 a) the femur image was everywhere limited by sharp contours and the spongious bone substance was also well defined everywhere even in those parts of the bone situated far outside the tomographic plane Thus the tomographic plane could not be clearly defined in the image However those parts of the image deriving from structures far outside the plane appeared in a deformed shape and outside these parts a

Fig 5 Lateral projection Tomography of the mandibular joint of a skull embedded in plastic. The same tomographic movements as in Fig 4 The 10-circle tomography (c) gives rise to a tomogram free from errors of depiction

partial attenuation zone occurred Even in this latter zone an image of spongious bone substance was evident (Fig 3 d) The drill channel through the femoral neck was just barely visible as two thin bands projected over the head and neck of the femur

Hypocycloid tomography of the macerated femur in the same section likewise gave rise to sharp outer contours and well-defined spongious substance in the tomographic plane The contrast of all contours was somewhat lower than in the corresponding circular tomogram due to the larger tomographic angle Spongious substance situated outside the tomographic plane apeared sharply depicted as well but was more indistinctly demonstrated than the corresponding structures in the tomographic plane Therefore this plane could to a certain degree be defined from its surroundings in the tomogram The parts of the head and neck of the femur located outside the tomographic plane were sharply depicted but the image was deformed and was surrounded by a partial attenuation zone In certain parts this partial attenuation zone was limited by double spurious contours in accordance with the geometric properties of the hypocycloid movement path In the partial attenuation zone the spongious bone was faintly visible The drill channel was barely visible as four different thin zones However their contrast was too low to be reproducible in print

When the femur was depicted by means of 10-circle tomography (Fig 3 c) sharp contours and distinct spongious bone substance were seen in the tomographic plane This plane was distinctly defined against its surroundings where the contours appeared unsharp and the spongious bone had disappeared completely Since the most posterior part of the femoral head was traversed by the tomographic plane

a small area of sharply depicted spongious bone appeared in this place In no other tomogram could it be established that this small area belonged to the tomographic plane The shape of the object was kept completely intact without any visible deformation even in those parts where blurring existed The drill channel was visible as one single unsharp zone situated at its proper place in the head and neck part of the femur The unsharpness indicated that the drill channel was situated outside the tomographic plane

The objects tomographed were characterised by rather great absorption differences However the skull phantom embedded in plastic gave rise to more ordinary differences of absorption In tomography of the ear and the mandibular joint superimposition is a rather disturbing factor when screen film systems are used Thus these two objects made it possible to analyze in xerographic images the tomographic blurring of objects with ordinary absorption properties as well as the influence of superimposition

Xerographic tomography with a circular movement path gave rise to sharp contours from object parts situated in the tomographic plane but the spurious contours were very disturbing (Figs 4 a 5 a) For this reason the tomogram was considered unsuitable for ordinary radiographic work In the ear tomogram spurious contours *appeared deriving even from the orbit Part of the mastoid process appeared in* sharp spurious contours when the tomographic plane passed through the middle of the external auditory meatus (Fig 4 a) In the tomograms made by means of the circular tomographic movement nothing indicated any obvious disturbance from superimposition Thus in xerographic tomography with a circular movement the end result was severely disturbed by spurious contours superimposition not giving rise to any disturbance worth mentioning

For the hypocycloid movement the results were rather similar to those obtained with the circular movement (Figs 4 b 5 b) As noted in the femur tomograms the higher tomographic angle led to diminished disturbance from spurious contours The spurious depiction of the mastoid process in the ear tomograms still appeared *No adverse influence from superimposition occurred*

In 10-circle tomography of the skull phantom the tomographic plane and its vicinity giving rise to true tomographic depiction were clearly demarcated from its surroundings due to the total disappearance of spurious contours (Figs 4 c 5 c) For this reason the mastoid process was completely blurred when the tomographic plane passed through the middle of the external auditory meatus No influence from superimposition appeared Thus with this optimised tomographic movement xerographic tomograms without any noticeable errors of depiction were produced

Discussion

The edge contrast enhancement of the xerographic plates gives rise to increased visibility not only of true contours but of spurious contours as well The impression

was gained throughout that the spurious contours were more disturbing in xerographic tomography than is usual in screen film tomography The reason for this is not clear Anyhow this indicates that xerographic tomography imposes higher demands on the quality of the tomographic blurring than is generally considered necessary in screen film tomography To achieve this higher blurring quality it is necessary to use optimised tomographic movements of the kind constructed for conventional radiography (ÅSTRAND & REICHMANN) In the present investigation it has been demonstrated that the same geometric properties of the movement path as well as the dose distribution may be used for xerographic tomography as for screen film tomography Thus the same construction can be used in both cases Since the Xerox plates need a higher quality of blurring it appears justified to conclude that any practical tomographic construction should be tested with Xerox plates rather than with screen film combinations

In spiral tomography using several revolutions in the movement path each half of the partial attenuation zone contains as many spurious contours as there are revolutions in the movement path When the number of revolutions is increased the spurious contours tend to lose their visibility as a result of an increasingly unfavourable signal/noise ratio (ÅSTRAND & REICHMANN) An important source of noise in this type of screen film tomography is in fact constituted by the contours themselves This means that a contour is difficult to demonstrate because of the very fact that there are spurious contours very close to it on each side A spurious contour which could be visible when it was alone was thus made more or less invisible when a number of contours were added on both sides of it The spurious contours were always sharp but they formed a sort of background noise to each other this noise being the reason for the visible impression of blurring This peculiar effect appears to be encountered in Xerographic tomography as well despite the great differences in depiction of sharp contours between Xerox plates and screen film combinations

The Xerox medium tends not to depict such absorption differences as are unsharply projected onto the plate The medium also has a very large exposure latitude These two properties in combination counteract the disturbing superimpositions which are generally encountered in screen film tomography A Xerox tomogram thus contains only sharp contours regardless of the form of the tomographic movement path Even when circular or hypocycloid movements are used only sharp contours appear in the tomograms This absence of unsharp blackening differences appears to have led SCHERTEL (1975) to believe the tomographic cut section layer to be more strictly defined in the direction of the radiation when xerographic tomography is used However this is not the case in conventional tomographic movements since the spurious contours deriving from structures far outside the tomographic layer appear as well When high quality blurring is used as may be obtained by means of a 10 revolution tomographic movement path the spurious contours are eliminated and in this case a section which is rather well

defined in the direction of the radiation is obtained For such a clear demarcation of the section against the surroundings to be achieved the combined elimination of superimposition and spurious contours is necessary

Xerox plates are insensitive to roentgen radiation and so the dose to the patient tends to become very high (SCHERTEL et coll 1974 HARLE et coll 1975) The sam type of depiction as is encountered in xeroradiography may be obtained by using other types of recording media JOHNS et coll (1974) replaced the s lenium plates by an ionization chamber containing high pressure xenon gas This medium is considerably more sensitive than the Xerox plates of today When the usefulness of such chambers is evaluated for tomographic purposes the thickness of the recording medium must be considered The gas chamber in question has a thickness of about 1 cm The effects of such thick recording media on tomographic depiction cannot be anticipated It may well be that this type of recording medium will give good tomographic depiction of a layer of about the same thickness within the body This would imply an interesting way to accomplish zonography even with large tomographic angles However it may also be that the thickness of this recording medium makes it completely unsuitable for tomography If the chambers are unsuitable the Xerox plates will have to be modified in order to reduce the doses One possibility is offered by simultaneous multisection tomography The Xerox plates may be expected to be more suited to this type of tomography than screen film combinations since the Xerox plates have a much larger exposure latitude and a much smaller sensitivity to secondary radiation (SELIN et coll 1975) these two factors causing low image quality when multisection tomography is performed by means of intensifying screens (WIDENMANN 1958) The problem in multisection Xerox tomography will probably be to place the selenium layers at sufficiently small distances from each other without the electric charges of one plate affecting the charges of the nearest plates If these problems can be solved several tomograms will be produced by means of the radiation dose producing one Xerox tomogram today

SUMMARY

Tomographic depiction using Xerox plates was compared with that of screen film tomo graphy The Xerox plates entail much higher demands as to the quality of tomograph c blurring than screen film combinations Circular or hypocycloid movements give rise to errors of depiction which are more disturbing in xerographic tomography due to the fact that the screen film combination has such properties as to be unable to record certain spurious signals present in the radiation relief which appear in the higher precision recording of the Xerox plates This indicates that these plates are to be preferred if only the spurious signals can be eliminated Suitable tomographic movements are described To counteract the high radiation doses in xerotomography it is suggested that specially constructed cassettes for simultaneous multisection tomography should be used

ZUSAMMENFASSUNG

Die tomographische Abbildung unter Verwendung von Xeroxplatten wurde mit derjenigen der Schirm Film Tomographie verglichen Die Xeroxplatten stellen wesentlich hohere Anforderungen an die Qualitat der tomographischen Unschärfe als Schirm Film Kombinationen Zirkulare oder hypozykoidale Bewegungen fuhren zu Abbildungsfehlern welche bei der xerographischen Tomographie deshalb mehr storen weil die Schirm Film Kombination solche Eigenschaften hat die sie ungeeignet macht gewisse falsche Signale im Strahlenrelief zu registrieren welche bei der Hochprazisonswiedergabe der Xeroxplatten auftreten Das deutet darauf hin dass diese Platten nur dann vorzuziehen sind wenn die falschen Signale eliminiert werden konnen Geeignete tomographische Bewegungen werden beschrieben Um den hohen Strahlendosen bei der Xerotomographie entgegenzuwirken wird vorgeschlagen speziell konstruierte Kassetten fur Simultanschichtaufnahmen zu verwenden

RESUME

L image tomographique obtenue au moyen de plaques Xerox a éte comparee avec celle que donne la tomographie avec des écrans et des films Les plaques Xerox necessitent une bien meilleure qualite de l effacement tomographique que les combinaisons films-écran Les mouvements circulaire ou hypocycloidal donnent lieu a des erreurs de representation de l objet qui sont plus genantes en tomographie xerographique ceci est du au fait que la combinaison écran films a des propriétes qui la rendent incapable d enregistrer certains signaux trompeurs qui sont presents dans le relief de radiations et qui apparaissent dans l enregistrement de plus haute précision qui caracterise les plaques Xerox Ceci montre que ces plaques ne doivent etre preférees que si on peut éliminer les signaux trompeurs Les auteurs décrivent les mouvements tomographique convenables pour contrebalancer les fortes doses nécessaires en xérotomographie les auteurs proposent d utiliser des cassettes specialement construites pour la tomographie multiple simultanee

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Book review

ERKRANKUNGEN DES HERZMUSKELS Klinisch radiologisches Seminar Band 5 Edited by W Frommhold and P Gerhardt 170 pages with 130 figures Georg Thieme Verlag Stuttgart 1976 Price DM 56 —

Several authors have contributed to this review of the pathology of the myocard

The first short chapter written by K A Puff gives the topographical anatomy of the heart The Latin names of the arteries are used The author remarks that the nomenclature given in Nomina anatomica does not include all parts of the coronary vascular anatomy The pathology of the myocard is described by K Goerttler This valuable chapter includes a useful list of reference

The physiology of the myocard is reviewed by R Jacob in a very condensed part of the book The complicated matter could have been illustrated with more simplified and better explained figures Previous knowledge is necessary for a clear understanding

The topography of the heart as revealed by roentgen examination is treated by P Thurn in a short accurate form with good illustrations

Heart volume determinations are discussed by J Emmerich in a short chapter including most of the present experiences from Germany and Sweden The determination of the length of the axes should have been discussed in more detail The importance of measuring the total heart volume in supine or prone position is emphasized The recommendation of a film focus distance of 200 cm seems to be too categoric Some references in the opinion of the reviewer important are lacking

Determination of the left ventricular volume is discussed by D Jeschke without satisfactory discussion of the sources of error The author considers that in the future echocardiography will replace cardioangiography in determination of the left ventricular volume which seems to be an overestimation of the possibilities of the echo-cardiography From a mathematic point of view the echo-cardiographic methods for determination of left ventricular volume are not precise

The clinic of cardiomyopathies is well treated by K Kochsiek in a chapter up to date with good references The radiologic diagnosis of left heart insufficiency is discussed by W A Fuchs in a short chapter which includes a comprehensive revi w of the pathophysiology The terminology is oldfashioned and reflects the tendency to describe the appearances of the film instead of using the anatomic or pathologic designation of the underlying condition or structure instead of Kerley s lines the expression oedematous interlobular septa should be used etc A short review of kymography and densitometry for analysis of the heart movements is given by J Li srer No references are given This technique may be of value for demonstrating dyskinetic and akinetic parts of the left ventricular wall for instance Isotope examinations including coronary blood flow determinations are briefly reviewed by U Feine but in the opinion of the reviewer critical view points on this important topic should have been given more place A chapter on rare cardiomyopathies by D W Behrenbeck is well written and contains much information Cor pulmonale is discussed from clinical view points by P Hilpert and its radiology by F Felix

Indications and contraindications for coronary angiography and the complications are summarized by U Larbig and the technique and findings by M Thelen and P Thurn Some references are not given in the list of references although the authors names are mentioned in the text Sones technique is considered as having a lower frequency of complication than Judkins technique However later reports not given in the list of references have stated that no difference exists The authors recommend a contrast medium with high iodine content However it is evident that media containing 300 mg I/ml or les are to be preferred

Oblique projections of the first part of the left coronary artery are not mentioned maybe because the authors are not using equipment for this technique

The last chapter deals with myocardial infarct and is written by P Scholmerich H J Just F Limburg and J Zipfel The prognosis and the hemodynamic changes are described as well as complications for instance left ventricular aneurysm

The book may be useful for radiologists who want a short description of the physiology and pathology of the heart as a background to the clinical radiography of the heart However the quality of these contributions varies and some do not reflect the most modern opinions

Uno Erikson

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LEFT CORONARY ARTERY TRANSIT TIME IN LATENT CORONARY HEART DISEASE

JAN ERIKSSEN and IVAR ENGE

Previous experiments in dogs have indicated that the time of appearance of contrast medium in the coronary sinus following injection of the medium in the left main coronary artery is reduced during hypoxia (SEMB & ENGE 1975) This phenomenon is due to vasodilatation induced by the hypoxia In human beings coronary artery disease may obstruct one or more of the vessels to such a degree that regional hypoxia may appear at rest During rest lesser degrees of obstruction are compensated for by vasodilatation thus coronary blood flow in the resting state does not fall below normal resting flow until an obstruction of about 80 per cent of the diameter is present (GOULD et coll 1975) This vasodilatation—similar to the one occurring during general hypoxia—should cause a shorter coronary artery transit time in cases of severe coronary artery disease but preliminary investigations failed to support this hypothesis (ENGE & NITTER HAUGE 1975) However this previous series represented mainly extremely advanced cases of coronary heart disease and it was thought appropriate to reconsider this problem in a less biased series of cases

Material and Methods

The material consisted of a consecutive series of 105 men with silent coronary artery disease revealed at a cardiovascular survey All were at full work none had signs of heart failure and none used cardioactive drugs The detailed modes of

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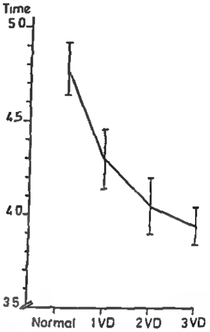


Fig 1 Coronary artery transit time in relation to number of diseased arteries (VD) in 104 patients with silent coronary heart disease 36 cases had normal angiographic findings One two and three arteries were diseased in 18 24 and 26 cases respectively

selections of the target population and the criteria used for performing coronary angiography as well as the findings are presented elsewhere (ERIKSSEN et coll 1976) Selective coronary cineangiography was performed according to JUDKINS (1967) Films were exposed in left and right anterior oblique and left lateral projections and when needed in additional projections The contrast medium was Isopaque Coronar (Na/Ca/I 58/911/370 mg/ml) and preshaped catheters (Ducor Cordis Corp , USA) were used All injections were made manually 4 to 8 ml per injection The arterial pressure was monitored via the catheter and invariably was normal before the in jection of the medium Recording of the cineangiography was made using an image intensifier with an Arriflex camera running at 75 frames/second

In order to assess the need for additional projections, the images recorded on video tape (OD X Oude Delft Holland) were immediately reviewed The degree of ar terial stenosis was assessed by measuring the diameter of the stenotic segment on films in at least two projections with reference to the prestenotic segment An ob struction was defined as significant if the stenosis in at least one projection reached 50 per cent or more in one of the main arteries or in major secondary branches

The coronary artery transit time was measured using a Tagarno 35 3 film analyzer (Tagarno Denmark) supplied with a frame counter The transit time was assessed according to the formula transit time (in seconds) = counted frames/75 frames

All films were reviewed on two separate occasions with an interval of at least one year and on both occasions the transit time was the average of two or more measure ments In order to minimize the influence of previous injections of contrast medium,

Table

t matrix for comparison of coronary artery transit time in 104 patients with silent coronary heart disease

	No of diseased arteries		
	One	Two	Three
No of diseased arteries			
One (n = 18)	—		
Two (n = 24)	t = 1 13	—	
Three (n = 26)	t = 2 09*	t = 0 76	—
None (n = 36)	t = 2.25*	t = 3 44 *	t = 4 92

* p<0 05 ** p<0 01 *** p<0 001

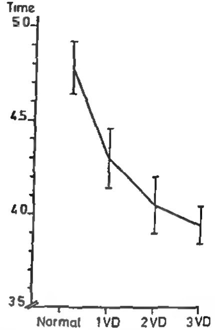
measurements were performed from the recordings of the first injection if long enough

The age of the patients was 40 to 59 years the mean age was 51 5 years in the group with no angiographic abnormality and 53 6 years in the pathologic group (SD in both groups 5 2 years) No one had a diagnosis of coronary heart disease at the time of the examination (ERIKSSEN et coll 1976) Eighteen had one artery 25 two arteries and 26 three diseased arteries and 36 had normal angiographic findings In all but 7 of the cases with pathologic angiographic findings at least one stenosis of 75 per cent or more of the artery was found No case was excluded from the series on account of the location of atheromatosis

Results

In one case with two diseased arteries the length of the cinerecordings was insufficient for the assessment of the transit time the patient was therefore excluded from the series which thus included 104 cases The mean coronary artery transit time in cases with normal angiographic findings was 4 78 s (SEM 0 145) in cases with one two or three diseased arteries 4 30 s (SEM 0 156) 4 05 s (SEM 0 153) and 3 92 s (SEM 0 100) respectively (Fig 1) The t matrix for the comparison of groups appears in the Table The transit time was significantly longer in the normal group than in all pathologic subgroups It was also significantly longer in cases with one artery than in cases with three arteries diseased whereas the differences were insignificant between cases with one and two and two and three arteries diseased respectively The severity of stenosis of the left anterior descending artery did not influence the transit time neither was it influenced by the type of vessel affected Thus the only factor influencing the transit time in the present material was whether one two or three arteries were diseased

The repeat measurements indicated an acceptable degree of reproducibility (Fig 2)



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The coronary artery transit time was measured using a Tagarno 35 3 film analyzer (Tagarno Denmark) supplied with a frame counter The transit time was assessed according to the formula transit time (in seconds) = counted frames/75 frames

All films were reviewed on two separate occasions with an interval of at least one year and on both occasions the transit time was the average of two or more measurements In order to minimize the influence of previous injections of contrast medium

sex severity of coronary heart disease and complicating disorders During the following period it was felt that still an inverse relation could exist between the extent of coronary heart disease and the coronary artery transit time according to random observations This initiated a trial of the hypothesis in a consecutive non biased group of cases with previously undiagnosed coronary heart disease a group in many respects significantly differing from the cases of coronary heart disease commonly met with However the present cases represent a more genuine disease group i e with less complicating disorders such as heart failure or longstanding disability Furthermore only 2 had ECG evidence of a previous (silent) myocardial infarction (ERIKSSEN et coll 1976) Still the patients in the present material had advanced coronary heart dis ase since only 7 of the cases with pathologic angiographic findings did not have at least one obstruction amounting to or exceeding 75 per cent (ERIKSSEN et coll 1976)

The results indicate a significantly reduced transit time in coronary artery disease Thus a shortened transit time may to some extent be considered as indicating a significant diseas of the coronary artery system However the overlap between normal and diseased cases is too large to provide an adequate diagnostic information in th individual case (Fig 2) Although the coronary sinus mainly drains the left anterior descending and circumflex artery tributaries the 3 cases with isolated right coronary artery lesions were not excluded since they did not differ from the remaining 15 cas s with one artery diseas d Furthermore the transit time was almost identical in the 17 cases with two diseased arteries in whom also the right coronary artery was dis ased and in the 7 cases with left anterior descending circumflex artery lesions as w ll It would appear that cases with one or two arteries diseased had similar transit times irrespective of the vessels involved

One source of overlap between the various groups was that slightly different amounts of contrast medium were injected in a random fashion In addition the injections were made manually and thus probably the pressure and speed of injection varied as well Less effect of the contrast medium on the vessels should be expected when small amounts are injected than when larger amounts are injected rapidly (GOULD et coll 1975) Thus the manual technique may give rise to an unpredictable vasodilatory effect on the coronary vessels

Another source of potential error would be left ventricular cineangiography with filling of the aortic root before coronary angiography However only selective coronary angiography was performed in the present material

The transit time of the contrast medium cannot be considered to represent the true blood circulation time as different contrast media give different transit times (ENGE) and also produce different degrees of vasodilatation Although Isopaque influences the arterial calibre significantly less than 4 other commonly used contrast media it still increased blood flow significantly from 30 seconds up to 5 minutes following the injection (ALMEN & TRAGARDH 1973) The reasons for this variation may be differences in osmolality viscosity ionic composition etc but to what extent these

factors influence the transit time is not known at present Thus the transit time only represents a crude approximation of the coronary circulation time

The present technique included injection of small doses of contrast medium to demonstrate the position of the catheter Such flushing doses may have caused an immediate effect on the vessels to such an extent that the angiography to follow was influenced by the contrast medium i e causing a reduction in transit time In the cases where the measurements from the left anterior oblique view had to be used previous angiographies might further have influenced the estimation No systematic assessment of this possible source of error has been undertaken but ought to be considered

In the group of normals the transit time was longer than that given in a previous report (ENGE & NITTER HAUGE 1975) However none of the normals in the two reports can be regarded as strictly normal since they all had clinical evidence of more or less severe coronary heart disease Furthermore in the present series a small vessel disease among the normals cannot be excluded nor the possibility of significant obstructions which may have been overlooked such as occlusion of arterial branches at their origin Still the results indicate that coronary artery transit time i e probably the true blood circulation time decreases with increasing severity of the coronary heart disease The duplicate measurements indicate that the present technique of measuring the transit time allows a reasonable degree of reproducibility In addition the clinical significance of coronary heart disease as well as the effect of drugs on the coronary arteries may be assessed by this technique

SUMMARY

In a group of 104 cases with possible silent coronary heart disease 36 had normal angiographic findings and 68 significant coronary artery disease The transit time of the contrast medium in the left coronary artery was significantly shorter in cases with abnormalities of the artery than in non afflicted cases The extent of arterial disease seemed to influence the transit time inversely whereas the location of the abnormalities did not influence the transit time

ZUSAMMENFASSUNG

Bei einer Gruppe von 104 Fallen mit einer moglichen asymptomatischen Kranzarterienerkrankung hatten 36 normale und 68 pathologische angiographische Befunde Die Durchflusszeit des Kontrastmittels durch die linke Kranzarterie war signifikant kurzer bei Fallen mit Veranderungen der Arterien als bei Fallen ohne Gefassveränderungen Der Grad der arteriellen Erkrankung scheint die Durchflusszeit umgekehrt zu beeinflussen wahrend die Lokalisation der Gefassveranderung die Durchflusszeit nicht beeinflusste

RÉSUMÉ

Sur un groupe de 104 malades pouvant avoir une affection coronarienne asymptomatique 36 avaient une angiographie normale et 68 avaient une atteinte importante des arteres coronaires. Le temps de transit du moyen de contraste dans l artère coronaire gauche était

notablement plus court dans les cas ou il y avait des anomalies de l artère que dans les cas normaux Le temps de transit a paru varier en sens inverse de l etendue de l atteinte artérielle alors que le siège des anomalies n a pas eu d influence sur le temps de transit

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Book review

Special Procedures in Chest Radiology By S S Sagel W B Saunders Co 1976

Several authors have contributed to the book which is divided into 7 chapters titled as follows Tomography Fluoroscopically assisted lung biopsy techniques Bronchography Pulmonary angiography Thoracic aortography Nuclear medicine in lung disease and Pediatric pulmonary techniques respectively It is lucidly written contains a lot of useful information and numerous high quality illustrations The monograph is intended to be useful for the radiologists in training as well as for those in clinical praxis Many of the procedures are described in great detail not going to much into theoretical considerations Indications and contraindications for each procedure are discussed and the findings in various diseases described Each chapter is concluded by a short list of fresh references however almost exclusively consisting of publications having appeared in the USA

The book obviously represents an attempt of a younger generation American radiologists to deviate from what has often been considered as being the traditional role of such a specialist in sitting at the light box reading films Instead a more intensive manual approach to diagnostic problems is advocated For a Scandinavian reader it is somewhat confusing what is meant by special procedures It seems strange that tomography used and misused in every small radiologic unit all over the world since the thirties should fall under such heading occupying 10 per cent of the available space The selection of topics while it probably reflects traditions in the States seems somewhat arbitrary It is obvious that the subject as reflected in the title of the individual chapters cannot be covered at any length on 219 pages to a great part occupied by illustrations The general reader may find lengthy discussions on minor technical points unnecessary the more as they are likely to vary among institutions Much is to be said about the proper disposition of the text under the various headings The unexperienced radiologist might for example in an emergency situation wish to look up contraindications for pulmonary angiography Under the proper heading he finds recent myocardial infarction (an opinion not shared by the reviewer) and *history of contrast medium reaction The most important contraindication or factor calling* for extreme cautiousness i e severe pulmonary arterial hypertension is for some reason hidden under the heading Site of the injection on the back page where it is likely to elude attention In most books of this type it is easy to find questionable statements and important omissions this one is not an exception Thus tomography is advocated sometimes to establish which organ contains the lesion the lungs ribs or the skin as if an oblique view full size film would not save time cost and irradiation dose Also in the chapter on tomography 17 out of 18 illustrations nicely bear out the thesis—regrettably not stated straight forward by the authors—that tomography of the lungs seldom provides information not already available from the conventional films provided these are correctly exposed and processed The pleading for a wider use of needle aspiration biopsy in cases of indeterminate solitary pulmonary lesions is underlined by citing works which state that the incidence of *malignancy is less than 20 per cent in peripheral pulmonary nodules! This figure is remarkably* low and certainly does not reflect the situation in the countries of Northern Europe today In the chapter on thoracic aortography the concept of aortic valve incompetence—a common and most important finding—is just mentioned under the heading Technique while the clinically insignificant kinking of the aorta or other rare aortic anomalies and pulmonary sequestration is dealt with at some length in separate entries

This critism should not hide the fact that the book contains valuable information in an amazingly small space and in easily digestable form It may be recommended as supplementary reading for radiologists intending to specialize or gaining working knowledge in thoracic radiology preferably accompanied by critical remarks of somebody already experienced in the field

Alfred Szamosi

FROM THE DEPARTMENT OF RADIOLOGY HARVARD MEDICAL SCHOOL AND PETER BENT BRIGHAM HOSPITAL BOSTON MASSACHUSETTS 02115 U S A

BLOOD FLOW IN PULMONARY AND BRONCHIAL ARTERIES IN ACUTE EXPERIMENTAL PNEUMONIA AND PULMONARY EMBOLISM

LARS BJORK and BARBARA J MCNEIL

Alterations in regional perfusion in patients with either embolic disease or pneumonia may be demonstrated on pulmonary angiography and scintigraphy Because it is likely that both the pulmonary and the bronchial artery circulations are altered by these conditions an attempt was made to define the nature of these changes in an experimental situation The interest was particularly focused on determining the relative magnitude of perfusion alterations in these two diseases relative to the normal state as well as in estimating the extent to which changes in one circulation followed changes in the other For these purposes rabbits with pulmonary embolism or carrageenin induced pneumonia were used

Acute pneumonia

Materials and Methods

White female New Zealand rabbits weighing about 2 500 g were used After intravenous injection of sodium thiopental the trachea was exposed through a midline incision and a tracheostomy performed A small catheter was introduced into the trachea and manipulated into the right lower lobe bronchus To prevent excessive coughing 0 2 to 0 3 ml of lidocaine solution 0 5 % was injected into the bronchioles Three to 5 ml of a sodium carrageenin solution 1 % were then injected while the position of the catheter and the injections were monitored with television fluoroscopy

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The injections were made with the rabbits in the right lateral position They were kept in that position during removal of the catheter and closure of the tracheostomy and skin

The presence of the carrageenin solution in the bronchial tree invariably led to a chemically and obstructively induced lobar pneumonia usually confined to the right lower lobe but occasionally involving the right middle lobe as well The technique is a modification of a method described previously (TRENCHARD et coll 1972)

Flow measurements Four to 6 days after the induction of pneumonia 7 rabbits were anesthetized A catheter was then passed from the femoral artery into the left ventricle and a butterfly needle was introduced in an ear vein

Flow measurements were performed using carbonized microspheres $15 \pm 5\ \mu$ in diameter labeled with either ^{85}Sr or ^{141}Ce (3M Company) and prepared as previously described (BARTRUM et coll 1974) The microsphere suspension was sonicated for 5 min at room temperature and the required volume was drawn into a disposable syringe within 15 seconds to avoid microsphere sedimentation (BUCKBERG et coll 1971) One ml containing 500 000 microspheres labeled with ^{141}Ce was injected intravenously over a 15 second period Four to 8 ml containing 2 to 4 million microspheres labeled with ^{85}Sr were then injected directly into the left ventricle over a period of 30 to 60 seconds After both injections the catheters and needles were flushed with 4 ml of heparinized saline

Four other rabbits were used to determine whether any of the ^{85}Sr particles injected into the left ventricle passed into the pulmonary system through the peripheral capillary bed or through bronchopulmonary shunts For this purpose 4 million particles were injected into the left ventricle and blood was continuously withdrawn from the pulmonary artery at a rate of 15 ml/min during the injection and 1 min after its termination The samples were then counted for 40 min and compared with background activity

All rabbits withstood the injections well and were killed after 10 min The chest was opened and the lungs removed The pneumonia in the right lower lobe always had the typical macroscopic appearance of a lobar pneumonia and was always clearly demarcated from uninvolved parts of the lung both macroscopically and microscopically It was carefully dissected from the uninvolved parts of the lobe the equivalent anatomic parts of the normal left lower lobe were then dissected to serve as a control

The right lower lobe with pneumonia and the normal left lower lobe were weighed and then divided into several counting tubes so that no specimen was ever more than 2 cm from the bottom of the tube Isotopic activity of the lung tissue was determined with a gamma well counter (Searle analytic scintillation counter) with a pulse height analyzer Each sample was counted for 20 min and the total amount of activity in each lobe was determined by summing the relevant tubes Since the pneumonia weighed 4 to 5 times more than the estimated similar anatomic parts of the normal left lobe the pneumonia and the normal lung were compared without correction for differences in weight

Table 1

Ratio of flows in left lower lobe to right lower lobe in normal rabbits (left/right)

Source of sample	Rabbit number								Mean	± SEM
	1	2	3	4	5	6	7	8		
Pulmonary artery	1.0	2.1	1.5	1.3	1.2	1.1	1.2	0.77	1.3	0.35
Bronchial artery	1.1	2.1	1.0	1.3	1.1	1.5	1.4	0.68	1.3	0.35

Measurement of the blood flow by this technique assumed that the number of particles (and hence isotopic activity) in area is directly proportional to blood flow in that area

Acute pulmonary embolism

Materials and Methods

White female New Zealand rabbits were again used After intravenous thiopental anesthesia the jugular vein on one side of the neck was surgically exposed and a 7 to 8 mm long segment was isolated and clamped off with rubber bands Trombine (20 IU) was injected into the isolated segment of the vein leading to the formation of a ca 7 mm × 2 mm solid autologous clot in the animal s own venous system (BJORK & ANSUSINHA 1965 HOLDEN et coll 1949) The clot was left to mature for 30 min The rubber bands were then released and the clot was propelled by the restored flow into the pulmonary circulation

Flow measurements Pulmonary embolism was induced in 8 rabbits After 1 hour microspheres were injected intravenously and into the left ventricle with the same technique as described The rabbits were killed after 10 min the lungs the heart and the mediastinal structures were removed en bloc The pulmonary artery was opened and the embolus localized The lobes or segments of the lung supplied by the embolized pulmonary artery branch were dissected and weighed their isotopic activity was determined as described Corresponding anatomic regions of approximately similar size in the non embolized lung were also dissected and used as controls The specimens were weighed and the number of counts was corrected for the weight of each specimen There was no difference in macroscopic appearance between embolized and normal lung

Control animals and comparative analyses

Flow measurements Eight healthy white female New Zealand rabbits were used as controls Microspheres were injected intravenously and into the left ventricle as described After killing the entire right and left lower lobes were dissected and counted

Table 2

Ratio between flow to the normal left lower lobe to the right lower lobe with carrageenin induced pneumonia (normal/abnormal)

Source of sample	Rabbit number							Mean	SEM
	1	2	3	4	5	6	7		
Pulmonary artery	13 8	2 5	7 3	6 1	6 2	7 1	16 8	8 5	1 8
Bronchial artery	**	1 8	5 7	6 5	7 9	**	3 1	5 0	1 1

* Rabbit No 2 had only scattered areas of pneumonia in the right lower lobe whereas the other 6 had solid lobar pneumonias

** Too few particles in specimen for statistically valid determination of the flow

Table 3

Ratio of flows in normal lung to lung with pulmonary emboli (normal/abnormal)

Source of sample	Rabbit number								Mean	SEM
	1	2	3	4	5	6	7	8		
Pulmonary artery	2 4	1 6	1 0	8 0	1 4	1 4	1 4	1 4	2 3	0 8
Bronchial artery	3 3	2 0	1 0	6 0	*	2 0	1 1	2 0	2 5	0 6

Too few particles in specimen for statistically valid determinations of the flow

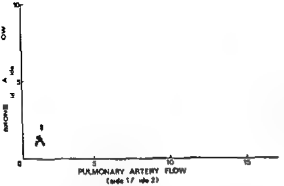
Comparison For both diseased states and for both the pulmonary artery and bronchial artery circulation the blood flow to one region of the lower lobe relative to the other (normal/abnormal) was compared with similar ratios for the control animals (left lung/right lung) Differences were analysed for significance by the Fisher exact test

The correlation between changes in flow in the pulmonary artery circulation and changes in the bronchial artery circulation was obtained by performing a linear regression of all pairs of flow ratios for all three sets of animals

Results

Flow ratios For the control animals the flow in the normal left lung was slightly greater than that in the normal right lung for both the pulmonary artery (^{141}Ce microspheres) and bronchial artery (^{85}Sr microspheres) circulations the ratios being 1 3 for both (Table 1)

For the animals with pneumonia the flow in the normal left lower lobe consistently exceeded the flow in the diseased right lower lobe for both circulations (Table 2) and was significantly different from the control animals ($p < 0\ 01$) The pulmonary artery



Relationship between flow changes in bronchial and pulmonary arteries for control and diseased animals The flow ratio on the ordinate is for the bronchial artery and on the abscissa, for the pulmonary artery For diseased animals side 1 is the normal one and side 2 the abnormal one for the control animals side 1 is the left lower lobe and side 2 the right lower lobe The correlation coefficient = 0 65

flow ratio between the normal and the pneumonic lobes varied from 2 5 to 16 8 (mean = 8 5) and the bronchial artery flow ratio varied from 1 [illegible] to 7 9 (mean = 5 0) In addition there was no evidence for either systemic or bronchopulmonary shunting of the [illegible] Sr particles used (i e no particles injected into the left ventricle passed into the pulmonary system)

The mean reductions in pulmonary and bronchial artery blood flow were less in acute pulmonary emboli than in pneumonia (Table 3) The pulmonary artery flow ratio ranged from 1 0 to 8 0 (mean = 2 3) and the mean bronchial artery flow ratio ranged from 1 0 to 6 0 (mean = 2 5) These ratios differed significantly from controls for the pulmonary artery circulation ($p < 0\ 01$) but not for the bronchial artery circulation

Correlations of changes in the two circulations There was a good correlation ($r = 0\ 65$) between the extent of change of flow in the bronchial artery circulation and in the pulmonary artery circulation (Figure) with the exception of one animal the correlation was essentially exact

Discussion

In acute pneumonia there is angiographic scintigraphic and microscopic evidence (STANDERTSKJÖLD NORDENSTAM 1965) that the pulmonary artery flow is reduced The bronchial artery circulation in acute pneumonia is generally considered to be increased (LIEBOW et coll 1959) However in 3 cases of lobar pneumonia in man the bronchial arteries post mortem were found to be blocked in the earlier phases of the pneumonia (CUDKOWICZ 1951) In the present experimental lobar pneumonia marked parallel reduction in both pulmonary artery and bronchial artery flow was found and there was no evidence for bronchopulmonary shunts Thus it is likely that the commonly held concept of increased bronchial artery circulation in acute inflammatory disease of the lung may have to be revised

The reduction of the pulmonary artery flow in pulmonary embolism has been attributed to a combination of several factors including mechanical blocking of the vascular bed reflux constrictions of vessels and bronchi and release of humoral

factors causing broncho and vasoconstriction (Ozdemir et coll 1974) Since the days of Virchow it has been generally accepted that the bronchial artery flow increases in areas of the lung affected by pulmonary embolism (Liebow et coll 1950) In the present experiments on the other hand reduction in pulmonary artery flow was associated with similar reduction in bronchial artery flow The magnitude of these changes were for the pulmonary artery circulation significantly greater than for control animals but for the bronchial artery circulation they were not significantly different These small changes probably result from varying degrees of obstruction in the pulmonary artery from animal to animal Since the animals were examined only one hour after the acute embolic episode it is possible that the reduced bronchial flow was temporary and would have been relieved in later stages of pulmonary embolism

The correlation between changes in the pulmonary artery and bronchial artery circulation in pneumonia and embolic disease suggests a common etiologic agent for the changes Local mechanical effects (edema intravascular clot compression of the vessels) reflex mechanisms or localized actions of humoral factors are all possibilities The present experiments do not allow differentiation of these

Acknowledgements

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SUMMARY

Acute lobar pneumonia and pulmonary embolism were induced in rabbits and the blood flow in the pulmonary artery and bronchial arteries was determined using isotopic microspheres In acute pneumonia the pulmonary artery flow to the involved lung was reduced 8 5 times and the bronchial artery flow was reduced 5 0 times compared to flow in the normal lung In acute pulmonary embolism both the pulmonary artery flow (2 3 times) and the bronchial artery flow (2 5 times) were also reduced For all animals the reduction in pulmonary artery flow paralleled the reduction in bronchial artery flow (r = 0 65)

ZUSAMMENFASSUNG

Bei Kaninchen wurde eine akute lobulare Pneumonie und Lungenembolie hervorgerufen und die Durchblutung der Arteria pulmonalis und der Arteriae bronchiales unter Verwendung von Isotopenmikrospheren untersucht Bei der akuten Pneumonie ist der Blutstrom der A pulmonalis der betroffenen Lunge 8 4 mal herabgesetzt und der Blutstrom der A bronchialis 5 mal herabgesetzt verglichen mit der Durchblutung der normalen Lunge Bei der akuten Lungenembolie ist sowohl die Durchblutung der A pulmonalis (2 3 mal) und die der A bronchialis (2 5 mal) herabgesetzt In allen Fallen folgte die herabgesetzte Durchblutung der A pulmonalis die Herabsetzung der Durchblutung der A bronchialis (r = 0 65)

RÉSUME

Les auteurs ont provoqué sur des lapins des pneumonies lobaires aigues [redacted] des embolies pulmonaires et ont déterminé le debit sanguin dans l artère pulmonaire et dans les artères bronchiques en utilisant des microsphères isotopiques Dans la pneumonie aigue le débit dans l artère pulmonaire du poumon concerné est réduit de 8 5 fois et le débit de l artère bronchique est reduit de 5 fois compare au débit dans le poumon normal Dans l embolie pulmonaire aigue le débit artériel pulmonaire (2 3 fois) et le débit artériel bronchique (2 5 fois) sont aussi réduits Pour tous les animaux la réduction du débit artériel pulmonaire est parallèle à la reduction du débit artériel bronchique (r = 0 65)

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Book review

QUANTITATIVE NUCLEAR CARDIOGRAPHY Edited by R N Pierson Jr J P Kriss R H Jones and W J MacIntyre A Wiley Biomedical Health Publication John Wiley and Sons New York London Sydney Toronto 1975 Price £12

The recent appearance of several monographs on cardiac nuclear medicine is a natural sequel of the rapidly increasing knowledge in this field Quantitative Nuclear Cardiography is one of these books Sixteen authors have participated in writing ten chapters (the first of them being a foreword for some reason titled introduction) on 282 page The first chapter after giving a short account of injection and positioning techniques and describing the main features of normal cardiac anatomy as seen with nuclide imaging deals mainly with information gained from computer processing of the primary data The authors are W J MacIntyre and J P Kriss The next chapter summarizes what the nuclear techniques of today give in congenital heart diseases viz the detection and quantitation of shunts written by R H Jones and P A W Andersson The impact of nuclear cardiography on the diagnosis and clinical evaluation of acquired heart diseases does not seem to be as great as in many other respects which put the author of chapter four J P Kriss in an unfavorable position at start Chapter 5 consists of a very well written discussion of various aspects of the analysis of left ventricular function by R N Pierson Jr and D C VanDyke It is followed by an account of the measurements of regional myocardial perfusion by W J MacIntyre P J Cannon and W W Ashburn In the next chapter F S Castellana tries to give a mathematical model of the central circulation a very difficult task indeed His account is accompanied by the critical remarks of J B Bassingthwaighte Instrumentation and radiopharmaceuticals used in nuclear cardiography are the topics of the next two chapters On the last few pages the imaging of acute myocardial infarction is discussed very shortly

In the opinion of the reviewer this is one of the best monographs in the field It is clearly and concisely written and—on the whole—well edited Many of the authors are among those best initiated in the particular problems treated There are numerous self-explaining charts curves and photographs in the book Each chapter is concluded by a short list of relevant references

For the reviewer whose daily work is to a large part made up of clinical cardioangiography it is tempting to regard this book as a challenge The spatial resolution of nuclear cardiac imaging is of course still far below the resolution provided by the well equipped laboratory of cardiac radiology In a way it reminds us of the early cinecardioangiography a couple of decades ago Beside the lack of trauma the obviation of the unphysiologic effects accompanying the introduction of large amount of contrast medium it is mainly the inherent possibilities of quantitation which may give nuclear technique a certain advantage *over conventional radiologic techniques at least in the eyes of the cardiologist and cardiac* physiologist In the foreseeable future a certain amount of competition can therefore be anticipated between the two methods wherever they both are available As for the present it shows the sound clinical judgement of the authors when they—as in chapter four dealing with acquired heart diseases—recommend the method for evaluation of patients sensitive to radiographic contrast media or too ill to undergo cardiac catheterisation and for comparable groups of patients As for measurement of regional myocardial perfusion there is of course no other method for the time being to compete with the nuclear technique

In a monograph of this type it is only too easy to find some statement already obsolete lack of mentioning some technique which to the reviewer appears more important or promising some unevenness or lack of proportions between the various parts On the whole it is an excellent book which can be highly recommended to anybody interested in the use of nuclear techniques in cardiology

Alfred S amosi

FROM DEPARTMENT OF MEDICINE VIII AND THE DEPARTMENT OF RADIOLOGY ULLEVÅL SYKEHUS OSLO

VECTORCARDIOGRAPHIC CHANGES AT SELECTIVE CORONARY ANGIOGRAPHY

Comparison of two contrast media

K NORDLIE H EIE and E. SIVERTSSEN

During selective coronary angiography characteristic changes are found on the ECG (BENCHIMOL & MCNALLY 1966 COSKEY & MAGIDSON 1967 SMITH et coll 1967 MAYTIN et coll 1970 EIE et coll 1972, GRENDAHL et coll 1972 BENCHIMOL et coll 1973) Left coronary angiography is associated with a shift of the mean QRS axis towards the left and the mean T axis towards the right Conversely right coronary angiography provokes the opposite axial shifts These changes have been termed left and right coronary artery response respectively (COSKEY & MAGIDSON) Vector cardiography with the Frank lead system at coronary angiography has also been carried out SMITH et coll found that the T vector changes were more marked than the QRS vector changes The degree of T vector changes and the slowing of heart rate were roughly proportional to the amount of contrast medium delivered to the coronary arteries the degree of the changes also being dependent on the patency of the arteries Similar observations have been reported by GRENDAHL et coll The shifts of the QRS axis have been attributed to alternations in the conduction system resulting in left anterior hemiblock at left coronary angiography and left posterior hemiblock at right coronary angiography The changes may also be due to peripheral block (FERNANDEZ et coll 1970 MAYTIN et coll BENCHIMOL et coll) The effect on the conduction system may be caused by ischaemia when the contrast medium replaces blood

Submitted for publication 10 September 1976

Table 1

*Osmotic properties and iodine content of the contrast media used (nominal composition)**

Contrast medium	Iodine content mg I/ml at 20 C	Osmolality mol/kg		Molal osmotic coefficient		Thermodynamic water activity	
		37 C	60 C	37 C	60 C	37 C	60 C
Isopaque Coronar	370	2 15	(2 07)	0 712	(0 686)	0 9620	(0 9634)
Urografin 60	292 4	1 52	1 45	0 720	0 688	0 9731	0 9743

* Figures in parentheses have been evaluated by wider extrapolation and may be less accurate From BORDALEN et coll

(BENCHIMOL & MCNALLY) However other authors have suggested that the changes are mainly due to toxicity of the components of the contrast media affecting both depolarization and repolarization (EIE et coll ; GRENDAHL et coll) The content of sodium ions seems to be the most important factor in producing this effect (GUZMAN & WEST 1959 GENSINI & DIGIORGI 1964) Coronary artery injection of Ringer s solution heparinized venous blood or plasma do not provoke these changes (GUZMAN & WEST GENSINI & DIGIORGI SMITH et coll EIE et coll GRENDAHL et coll)

Disturbances of the heart rhythm are often recorded during coronary angiography a shortlasting sinus bradycardia being the most common one Severe arrhythmias seldom occur

If the VCG changes be accepted as a result of toxic action of the contrast medium the vectorcardiographic changes that arise at selective coronary angiography may be used to evaluate the toxicity of contrast media In the present report the effect of different doses of two contrast media are compared

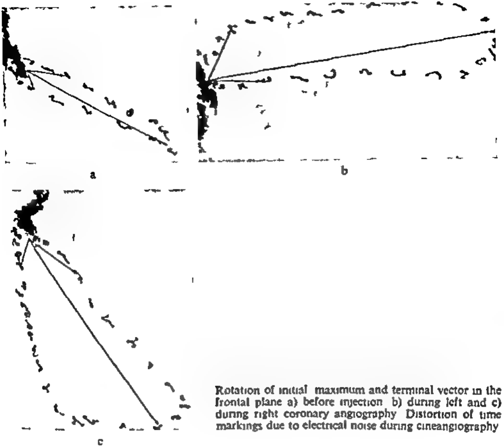
Material and Methods

Coronary angiography was carried out in 29 patients using both Urografin 60 ₀ and Isopaque Coronar (Nyegaard) The osmotic properties and iodine contents of the media appear in Table 1

All examinations were performed according to Judkins technique with cine angiography and manual injections Equal amounts of contrast media were injected into the same artery but the dose varied from 6 to 9 ml in the different arteries or grafts

All recordings of the ECG took place on a Hewlett Packard oscilloscope vector cardiograph Frank leads X Y and Z were continuously transmitted from the vector cardiograph to a 4 channel Tandberg tape recorder (Tandberg Norway)

The fourth channel indicated the start and end of the injection as well as the appearance of the maximum axis shift in the horizontal (H) frontal (F) and right sagittal plane (SR)



Rotation of initial maximum and terminal vector in the frontal plane a) before injection b) during left and c) during right coronary angiography Distortion of time markings due to electrical noise during cineangiography

The maximum changes usually occurred 5 to 6 s after the beginning of the injection and lasted 2 to 3 s allowing the recording of 2 to 4 identical loops only the QRS loops were analysed The maximum deviation from the basal situation of the following parameters was measured in all planes for each injection (Figure) (1) rotation of the maximum QRS vector (2) rotation of the initial (10 ms) vector (3) rotation of the terminal QRS vector and (4) changes of the magnitude of the maximum QRS vector

The maximum deviations were measured in the three planes separately Statistically significant differences are defined at the 5 per cent level or smaller ($p < 0.05$)

Results

Different doses of Urografin Thirty one coronary arteries and 22 aortocoronary shunts were examined with 1 ml 5 ml and 8 ml of Urografin 60 . The injection of 1 ml of the contrast medium did not provoke any arrhythmias and the VCG changes were too small to be measured with any degree of accuracy and are excluded from the table

The results of the comparison of 5 ml versus 8 ml of the contrast medium appear in Table 2 The injection of 5 ml sometimes caused greater changes than the injection of

Table 2

VCG changes at injection of 5 ml and 8 ml Urografin 60 % in 32 coronary arteries at selective angiography The values are the means of the maximum changes in each patient

VCG changes	Plane	5 ml	8 ml
Maximum vector rotation in degrees	H	16	20
	RS	29*	36*
	F	18*	23*
Initial vector rotation in degrees	H	23	19
	RS	53*	64*
	F	30	31
Terminal vector rotation in degrees	H	15	19
	RS	41	40
	F	56	64
Amplitude change of maximum vector rotation in per cent	H	34	38
	RS	102	87
	F	126	154

H Horizontal plane RS Right sagittal plane F Frontal plane * Statistically significant difference

8 ml in single planes and parameters but the trend was that VCG changes were greater on injection of 8 ml than following the administration of 5 ml The differences were statistically significant concerning the rotation of the maximum vector in the right sagittal and frontal planes and the rotation of the initial vector in the right sagittal plane A shortlasting sinus bradycardia was often observed but no difference in the incidence of bradycardia irrespective of whether 5 ml or 8 ml of contrast medium were injected No other complications occurred

Comparison between Urografin and Isopaque Coronar Sixty three coronary arteries and aortocoronary shunts in 29 patients were examined with both Urografin 60 % and Isopaque Coronar

The sequence of contrast medium used was randomized and neither the cardiologist nor the radiologist knew which contrast medium had been used when the cinefilms and VCG recordings were examined The results of the comparison are demonstrated in Table 3 Only very small differences in the maximum VCG changes following injection of the two contrast media were recorded and no statistically significant differences were found in any plane or parameter

A shortlasting sinus bradycardia was observed following injection in all vessels in some patients independent of the medium used Ventricular fibrillation occurred in one patient during the catheterization of the right coronary artery it was probably caused by the catheter occluding the ostium and was not due to the injection of contrast medium Defibrillation was successfully performed No other severe complications occurred

Table 3

VCG changes at selective coronary angiography with Urografin 60 and Isopaque Coronar in 32 coronary arteries and 22 aortocoronary bypasses The values are the means of the maximum changes in each patient

VCG changes	Plane	Urografin 60	Isopaque Coronar
Maximum vector rotation in degrees	H	20	24
	RS	39	37
	F	19	20
Initial vector rotation in degrees	H	20	22
	RS	34	38
	F	21	24
Terminal vector rotation in degrees	H	22	21
	RS	28	30
	F	50	53
Amplitude change of maximum vector rotation in per cent	H	24	24
	RS	26	24
	F	24	24

H Horizontal plane RS Right sagittal plane F Frontal plane

Discussion

Significant VCG changes were observed when the 5 ml and 8 ml injection responses were compared with those of the initial recordings before the injections of contrast media In this department 5 ml and 8 ml are the volumes used for selective right and left coronary angiography respectively

In angiography of aortocoronary shunt 8 ml was injected routinely All injections were performed manually A more constant flow may be obtained with an injection device but this is not regarded as being as safe for the patient as a manual injection The filling of the vessels was satisfactory in all cases The response was more marked with 8 ml than with 5 ml and particularly concerned the maximum vector the same trend was apparent as regards the other vectors recorded The incidence of sinus bradycardia was the same in the two groups

Isopaque Coronar is a relatively new contrast medium and has until recently not been used in selective coronary angiography in this hospital The comparison of Urografin 60 and Isopaque Coronar did not reveal any significant differences in the VCG response following injection into the coronary arteries and no difference in the incidence of arrhythmias occurred Thus the two contrast media must be considered equivalent with respect to VCG changes following coronary angiography although Isopaque Coronar has a higher iodine content (370 mg I/ml) than Urografin 60 ° (292 mg I/ml) The quality of the films was the same

SUMMARY

Vectorcardiography reveal d typical changes following routine selective coronary angiography using Urografin 60% and Isopaque Coronar the response was dose dependent The two contrast media compared well with one another no statistical difference being recorded indicating that there is no difference in myocardial toxicity

ZUSAMMENFASSUNG

Die Vektorkardiographie lasst typische Veranderungen nach einer routinemassig n selektiven Angiographie der Koronargefasse unter Verwendung von Urografin 60 % und Isopaque Coronar erkennen die Veranderungen waren Dosisberuhend Die beiden Kontrastmittel waren einander vergleichbar keine statistischen Unterschiede wurden festgestellt was darauf hinweist dass keine Unterschiede in der Toxizitat gegenuber dem Myokard vorliegen

RESUME

La vectocardiographie a montre des modifications typiques après angiographie coronarienne selective classique utilisant l Urografin 60° et l Isopaque Coronar ces modifications dependent de la dose Ces deux moyens de contraste sont comparables ne donnant pas lieu a une difference statistique ce qui prouve qu il n y a pas de difference de toxicité pour le myocarde

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COMPARISON OF THE LEFT VENTRICULAR VOLUME USING THE AHLBERG AND DODGE METHODS

IVO BERANEK RICHARD MOORE SUNG KIM and KURT AMPLATZ

Determination of the left ventricular volume from cine left ventriculograms is an important part of the clinical assessment of patients with coronary artery disease (MIRSKY et coll 1974) The results from calculation of the ejection fraction are useful for the management of these patients Such determinations aid in the decision whether medical or surgical treatment is indicated (OLDHAM et coll 1972) and help to evaluate the effectiveness of surgical or medical treatment They are important for deciding the prognosis of these patients (COHN et coll 1974)

Many methods have been described to calculate the volume of the left ventricle using radiographic measurements made from single or biplane cine left ventriculograms (DODGE & TANNENBAUM 1956 CHAPMAN et coll 1958 DAVILA & SAN MARCO 1966 GREENE et coll 1967 HERMANN & BARTLE 1968 KASSER & KENNEDY 1969) Most methods employ a modification of Simpson s rule (CHAPMAN et coll DAVILA & SAN MARCO) or assume that the ventricle can be represented by an ellipsoid of revolution (DODGE & TANNENBAUM GREENE et coll)

A different method was introduced by AHLBERG et coll (1973) The method is based on a new mathematical model The authors claimed that their method is more reliable for calculating volumes of both the normal and abnormal left ventricles Intuitively AHLBERG s method appears better especially if the left ventricle is distorted by ischemic heart disease The Ahlberg method was confirmed only in dogs for which a correction factor was not found to be necessary as is the case for humans (CHAPMAN et coll DAVILA & SAN MARCO GREENE et coll SANDLER & DODGE 1971 MIRSKY et coll)

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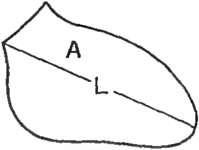


Fig 1 Dodge method The longest axis (L) is constructed and measured in the tracing of the left ventricular cavity The area (A) of the tracing is planimetered The volume (V) is calculated using $V = \frac{8}{3\pi}(A^2/L)K^3$ (K a linear correction factor for distortion due to nonparallel rays)

It is the purpose of this report to compare the Ahlberg method with the Dodge area-length method in human cine left ventriculograms The Dodge method is most commonly used to calculate the left ventricular volume in men being well documented and authenticated (DAVILA & SAN MARCO HERMANN & BARTLE SANDLER & DODGE MIRSKY et coll) Consequently it was the logical choice as a reference method

Materials and Method

Twenty four patients with ischemic heart disease were selected Twelve patients had a normal ventricular contraction and twelve had abnormalities (akinesia or dyskinesia) Single plane cine left ventriculography (60 frames/s) was performed in a 30 right anterior oblique (RAO) position in which the longest axis of the left *ventricle is approximately parallel to the plane of the input phosphor of the image* intensifier The silhouette of the left ventricle was traced in end diastole and in end systole From each of these tracings the volume of the left ventricle was calculated using both the Dodge (Fig 1) and Ahlberg (Fig 2 a b) methods Both methods were used to calculate the end diastolic volume (EDV) end systolic volume (ESV) and ejection fraction (EF) This procedure eliminated several sources of variation, such as possible error in selecting the correct cine frame and subjective errors in estimating the border A correction was made for distortion from non parallel rays according to DODGE & TANNENBAUM All the measurements and calculations were made by one person thus eliminating inter observer variation

Theoretic considerations and description of the Ahlberg method The shape and movement of the ventricle during myocardial ischemia is not uniform If the cavity of the ventricle is assumed to be circular in cross section and the ventricle bulges only in one direction its volume may be calculated as follows The left ventricular cavity is considered to be a symmetric three dimensional body through which a circular area moves The diameter of the area varies as it moves with its center along a curved line This moving area must always be perpendicular to the central line It should pass once and only once through each point within the ventricle (Fig 2 c) The curved line ($0 - S_0$) *is called the left ventricular midline It is the path followed* by the central point of diameter (l) of the circular area moving through the ventricle The values of the length of the diameter (l) are squared and plotted against the dis

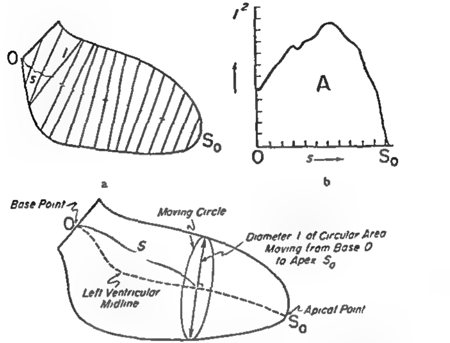


Fig. 2 Ahlberg method a) In the tracing of the left ventricular cavity the ventricular midline $(0 - S_0)$ is drawn from the base point (0) to the apex (S) The minor chords are drawn perpendicular to this midline at increments of 0 5 cm b) The lengths of the minor chords (l) are squared the values are plotted against th length(s) of the minor chord from the base point (0) measured along the ventricular midline The area (A) of the figure constructed in the $l^2 - s$ coordinate system is then planimetered The volume (V) is calculated using $V = \frac{\pi}{4} AK^3$ (K a linear correction factor for distortion due to non parallel rays) c) Drawing showing the motion of the hypothetical circular area from base to apex of the ventricular tracing. The outline of the ventricle is traced representing the projection of the 3-dimensional chamber onto a plane A circular area is imagined which travels along the silhouette from base to apex The midline is the path taken by the midpoint of the diameter of this moving circular area

tance (s) of the diameter from the base measured along the midline (Fig 2 b) The area (A) under the curve is given by

$$A = \int_0^{s_0} l^2(s)\,ds \tag{1}$$

In the three dimensional body where (l) is the diameter in the circular area moving along the arc of length (s) the volume (V) of the body will be given by

$$V = \frac{\pi}{4} \int_0^{s_0} l^2(s)\,ds \tag{2}$$

Thus the volume of the body is

$$V = \frac{\pi}{4} A \tag{3}$$

The area (A) in the l^2 vs s coordinate system (Fig 2 b) may be measured with a planimeter The volume (V) is then readily calculated

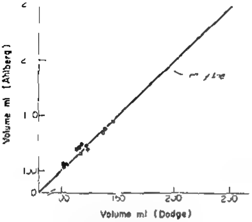


Fig 3

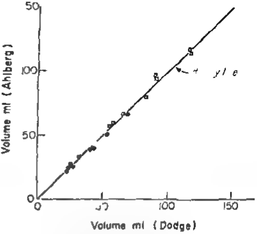


Fig 4

Fig 3 Comparison of end diastolic volumes calculated by Ahlberg and Dodge methods The value for end diastolic volume of the left ventricle calculated using the Ahlberg method is plotted against that using the Dodge method The identity line starts at the origin and has a slope of 45 If both methods yielded the same value the resulting point would lie on the identity line ● = the actual points for the normal subjects – the actual points for the patients with abnormalities of myocardial contraction

Fig 4 Comparison of end systolic volumes calculated by Ahlberg and Dodge methods

Small discrepancies exist between the shape of the mathematical model and that of the ventricular cavity in the projection used These discrepancies occur in the basal part of the chamber or in the ischemic portion which is deformed due to coronary occlusion If the circular area passes through each point only once then it may not always be perpendicular to the left ventricular midline However if the moving area is not perpendicular to the midline formula (2) may be corrected by replacing l^2 (s) with l^2 (s) $\cos\alpha$ where α is the angle between the moving area and the normal plane of the midline The consequences of these deviations from perpendicularity are considered to be negligible in the volume estimations because the values of $\cos\alpha_s$ are close to 1 0 and the sections of the midline involved are short

Results

Volumes were calculated using both the Ahlberg and Dodge methods The values of the results and the statistical analysis appear in Table 1 Figs 3 4 and 5 compare the results for EDV ESV and EF respectively

The points lie distributed approximately equally above and below the line at 45 degrees passing through the origin (the identity line) The clustering of the points around the identity line means that the coefficient of correlation of the results from the two methods is high (for EDV $r = 0\,97$ for ESV $r = 0\,99$ and for EF $r = 0\,96$) The closeness of the points to the identity line shows that there are no great differences

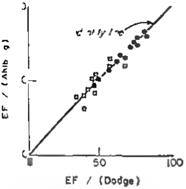


Fig 5 Comparison of ejection fractions calculated by Ahlberg and Dodge methods

between the values whether calculated by either the Ahlberg or the Dodge method ($p>0\ 05$) This is true not only for the normal but also for the abnormal cases and for EDV ESV and EF

The mean differences between the values from both methods and its standard deviation were small (for EDV 1 7 and 1 9 for ESV 1 5 and 1 1 and for EF −0 4 and 0 9 respectively)

Discussion

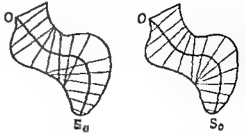
Surprisingly there were no significant differences between the results from either method regardless of whether the calculation was made for a normal or an abnormal left ventricle (Figs 3 4 5 and Table 1) The correlation coefficient for all parameters was high and differences were small (Table 1) It is believed that this finding can be explained by an examination of the Dodge method This method includes a kind of integration which is used for calculating the minor diameter from the planimetrically measured irregular area

Table 1

Comparison of values calculated by the Ahlberg and Dodge methods $\bar{x}$ mean SD $\bar{x}$ standard deviation of the mean $\overline{|x_1-x_2|}$ mean value of differences SD $\overline{|x_1-x_2|}$ standard deviation of the mean of differences t Student s t test y regression equation r correlation coefficient

Statistics	End diastolic volume (ml)		End systolic volume (ml)		Ejection fraction ( )	
	Ahlberg	Dodge	Ahlberg	Dodge	Ahlberg	Dodge
$\bar{x}$	139 7	141 4	60 9	62 4	58 7	58 3
SD $\bar{x}$	7 6	7 5	6 9	7 1	2 9	3 0
$\overline{\lvert x_1-x_2 \rvert}$	1 7		1 5		−0 4	
SD $\overline{\lvert x_1-x_2 \rvert}$	1 9		1 1		0 9	
t	0 (p>0 05)		1 338 (p>0 05)		−0 435 (p>0 05)	
y	7 ? (96 X		0 33+1 02 X		−0 13+1 00 X	
r	7		0 99		0 96	

Fig 6 Construction of the minor chords in the tracing of a left ventricle distorted by an aneurysm a) If the minor chords are constructed perpendicular to the midline ($0-S_0$) some of them crossed b) The minor chords have been constructed to avoid their crossing within the silhouette but with the loss of the perpendicular relation between some of them and the midline ($0-S_0$)



The results from the comparison indicate that the Ahlberg method yields almost the same values as the uncorrected Dodge method Therefore it does not provide any improvement in the accuracy of the volume The raw Dodge values must be corrected by an empirical factor (MIRSKY et coll) The same is true for the values from the Ahlberg method in man AHLBERG et coll using left ventriculograms in dogs also made a comparison between their method and the uncorrected method of DODGE for calculating EDV and ESV Values for the EDV from the two methods were clustered closely around the identity line In contrast AHLBERG s points representing the pairs of ESV did not cluster closely and symmetrically about the identity line The Dodge method produced ESV s which were uniformly greater than the Ahlberg method

Thus the comparison between the Ahlberg and Dodge methods for calculating EDV in man agreed with the comparison made by AHLBERG in dogs However the comparison for ESV in man disagreed with such a comparison made by AHLBERG in dogs It is likely that this discrepancy may partly be due to the species difference

AHLBERG also made plots for SV to compare the results of the ellipsoid method with those of a non radiologic technique the flow measurement In the present investigation a plot for SV was not made because given the EDV and ESV the SV is readily obtained Yet any errors in either EDV or ESV add to produce a doubly large error in SV Instead of SV plots for the EF were made which was felt to be clinically more useful

There are great differences between the Dodge and Ahlberg methods in practice If the Dodge method is calculated manually it yields results in a short time (5 to 10 min per case) It is feasible for computer programming On the other hand the Ahlberg method is very tedious for manual calculation requiring about one and a half hours per case In addition it is subject to more errors because it involves many more operations

One other problem with the Ahlberg method was the construction of the midline which is not clearly described in their paper Drawing the midline and the minor chords perpendicular to the midline is often a difficult task In addition the minor chords may cross especially with abnormal left ventricles (Fig 6 a) If a human observer draws the midline then the remainder of the work can be delegated to a computer which has been suitably programmed Recently such a development has

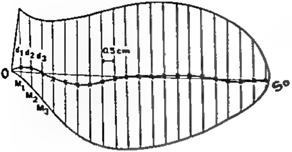


Fig 7 Modified construction of the midline Subjective estimation is eliminated ◼ base point S_0 apex —— longest axis according to Dodge d_1 d_2 minor diameters perpendicular to the longest axis M_1 M_2 midpoints of the short hemiaxes — modified midline

been reported (LIANDER et coll 1975) In Ahlberg s publications the minor chords were drawn in such a fashion that these intersections were eliminated Therefore negative areas were avoided although at the cost of losing the perpendicular relationship between the midline and the minor chord (Fig 6 b)

Appendix

The manuscript proper discussed the comparison between the results from the Ahlberg and Dodge methods This appendix is concerned with other aspects of the Ahlberg method, as follows

(a) problems in constructing the midline and a proposed alternate technique for its construction and

(b) avoiding the plot of l^2 vs s

(a) The original reference (AHLBERG et coll 1973) described the construction of the midline unclearly Sometimes the authors drew it simply by eye That means that the location of the midline could vary among radiologists which makes computer programming difficult

A possible alternate technique for constructing the midline which eliminates this subjective approach is as follows (Fig 7)

(1) The longest straight line is drawn between the apex and the LV base This major chord is the same as that drawn in the Dodge method
(2) Starting from the base point this line is divided into 0 5 cm increments
(3) Minor chords are drawn through each division point and perpendicular to the major chord from upper to lower ventricular edge
(4) Each minor chord is bisected
(5) A smooth curve is drawn through each bisecting point This curve is the alternate midline

(b) The Ahlberg method requires measuring the length (l) of each minor chord This length is squared and plotted against the distance (s) of the minor chord from the base A smooth curve is drawn through these points The area under the curve is used in AHLBERG s formula (3) $V = (\pi/4) A$ This area is represented graphically by the area under the curve in Fig 11 a The area under this curve is determined planimetrically Its value is used to calculate the volume of the ventricle (see eq 3) This method is tedious time consuming, and prone to error

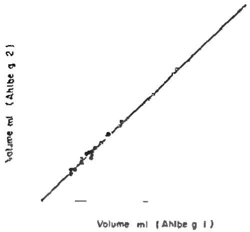


Fig 8

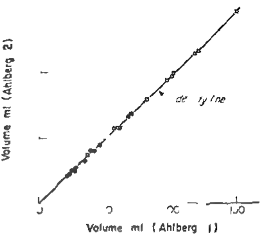


Fig 9

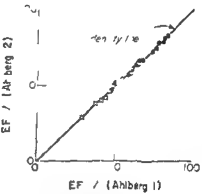


Fig 10

Fig. 8 Comparison of end diastolic volumes calculated by Ahlberg 2 and Ahlberg 1 methods

Fig 9 Comparison of end systolic volumes calculated by Ahlberg 1 and Ahlberg 2 methods

Fig. 10 Comparison of ejection fractions calculated by Ahlberg 2 and Ahlberg 1 methods

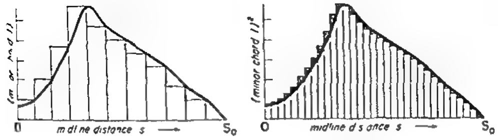
A different approach to obtain the area is now suggested. Each minor chord represents the base of a rectangle of height $h = 0.5$ cm. The total area is the sum of the areas of these rectangles (Fig 11)

$$A = \sum_{i=1}^{n} A_i = \sum_{i=1} h l_i = h \sum_{i=1}^{n} l_i \tag{5}$$

This area is represented graphically by the area under the rectangular bars in Fig 11 a. The difference between this value for the area and AHLBERG's value is represented graphically by the algebraic sum of the stippled areas in Fig 11 a. If the sum of the stippled areas on the left of the maximum equals the sum of the stippled areas on the right of the maximum then they cancel and the values for the area given by the two methods agree. If they do not cancel then there is a discrepancy between the values from the two methods.
The ventricular volume is given by

$$V = \frac{\pi}{4} h \sum_{i=1}^{n} (l_i^2) \tag{6}$$

This equation was used to calculate EDV, ESV and EF for all patients. The results were



a b

Fig. 11 Plot of l^2 vs s a) The plot made with s the distance along the midline divided coarsely The area under the heavy black curve is the area determined planimetrically in the original Ahlberg method The area under the horizontal tops of the bars represents the sum calculated in the proposed modification The stippled areas represent the difference between the area under the curve and the area under the bars b) The same plot with the midline distance divided finely The mezzotinted areas represent the difference between the area under the curve and the area under the bars In the limit, as the width of the rectangle decreases the area under the rectangles approaches the area under the smooth curve with infinitesimal error Thus the calculated sum may substitute for the planimetrically determined area

called the Ahlberg 2 values These values were compared with the results using the original Ahlberg method which we called the Ahlberg 1 values The pairs of values for EDV ESV and EF were plotted in Figs 8 9 and 10 respectively Table 2 shows the results of the statistical analysis The results were practically identical Consequently the graph of l^2 vs s can be replaced by the calculation of $\sum_1^n {}_1 (l_1^2)$ This change results in a difference in the sum calculated which depends on the height of the cylindrical slice Graphically this can be shown as the difference between the areas of Fig 11 a and b If the altitude is small enough the error becomes insignificant The results suggest that if h = 0 5 cm then this value of the altitude is sufficiently small Consequently the tedious and time-consuming construction of the area (A) and its planimetric measurement could be replaced by the faster mathematical calculation with practically the same results

Table 2

Comparison of values calculated by the Ahlberg 2 and Ahlberg 1 methods $\bar{x}$ mean SD $\bar{x}$ standard deviation of the mean $\overline{|x_1-x_2|}$ mean value of differences SD $|x_1-x_2|$ standard deviation of the mean of differences

Statistics	End diastolic volume (ml)		End systolic volume (ml)		Ejection fraction ( )	
	Ahlberg 2	Ahlberg 1	Ahlberg 2	Ahlberg 1	Ahlberg 2	Ahlberg 1
$\bar{x}$	141 4	141 7	62 4	62 3	58 3	58 2
SD $\bar{x}$	7 5	9	7 1	7 1	3 0	2.9
$\overline{\lvert x_1-x_2\rvert}$	0 3		−0 01		0 7	
SD $\lvert x_1-x_2\rvert$	0 8		0 1		0 6	

SUMMARY

Single plane cine left ventriculography was performed in 24 patients 12 with normal and 12 with abnormal ventricular shapes End diastolic and systolic volumes and ejection fractions were calculated by two methods (Ahlberg and Dodge) The volumes and ejection fraction from either method were not significantly different If calculated manually the Ahlberg method took ten times longer than the Dodge method At present some steps are difficult but a computer can perform the measurements and calculations and print the results for ventricular areas

ZUSAMMENFASSUNG

Eine Kineangiographie des linken Ventrikels in einer Ebene wurde bei 24 Patienten 12 mit normalen und 12 mit abnormalen Ventrikelformen vorgenommen Die enddiastolischen und endsystolischen Volumina und die Ejektionsfraktionen wurden mit 2 Methoden *Ahlberg und Dodge) berechnet Die Volumina und die Ejektionsfraktion unterschieden* sich bei den beiden Methoden nicht signifikant von einander Bei manueller Berechnung brauchte die Methode von Ahlberg 10 mal langere Zeit als die Methode von Dodge Zur Zeit sind einige Schritte schwierig aber ein Komputor kann die Messungen und Berechnungen durchfuhren und die Ergebnisse fur die Ventrikelabschnitte auszeichnen

RÉSUME

Une cinéventriculographie unidirectionnelle a été faite sur 24 malades dont 12 avaient une forme ventriculaire normale [redacted] 12 une forme ventriculaire anormale Les volumes à la fin de la diastole et de la systole et les fractions d éjection ont été calculés par deux méthodes (Ahlberg et Dodge) Les volumes et la fraction d éjection obtenus par les deux méthodes n ont pas presenté de différence significative Calculée manuellement la méthode d Ahlberg a pris dix fois plus de temps que la methode de Dodge A l heure actuelle certaines étapes sont difficiles mais l ordinateur peut effectuer ces mesures et ces calculs et imprimer les résultats pour les surfaces ventriculaires

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SITE OF ORIGIN OF DEEP VEIN THROMBUS IN THE CALF

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It is generally agreed that most venous thrombi start in the veins of the calf and spread proximally (BAUER 1940 1964 COTTON & CLARKE 1965 DODD & COCKETT 1956 1976 GIBBS 1957 NICOLIADES et coll 1970 1971) Confirmation for this view has been obtained more recently by the introduction of the ^{125}I fibrinogen test a method which detects thrombus with considerable accuracy (ATKINS & HAWKINS 1965 FLANC et coll 1968 NEGUS et coll 1968) However the exact site of origin of thrombus whether from the muscle veins the stem veins or both remains in doubt

This controversy results because most phlebographic techniques do not demonstrate the paired stem veins or the soleal veins sufficiently well to completely exclude thrombus in them Furthermore the fibrinogen test cannot distinguish between thrombus in the stem veins from thrombus in the muscle veins

A phlebographic technique for demonstrating the stem and muscle veins of the calf is described in this report which also analyses the site of thrombus in the veins displayed

Material and Methods

The phlebograms of 103 calves in [illegible] patients in which thrombus was known to be present but its exact site was not known to the observers were reviewed The site of the thrombus was displayed on diagrams of the veins of the calf to assist analysis

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Fig 1 a Fig 1 b Fig 2 a Fig 2 b

Fig 1 a) P a projection Thrombus in the stem veins of the calf The muscle veins obscured in this projection The anterior tibial veins not filled b) Lateral projection Thrombus in the stem and muscle veins (→) The thrombus is in continuity (↔) The anterior tibial veins (AT) filled

Fig 2 a) P a projection Thrombus in the lateral peroneal vein (→) b) Lateral projection The thrombus in the peroneal vein (→) No thrombus in the muscle veins

The observations were directed to the paired posterior tibial the peroneal and the anterior tibial veins (the stem veins) and the soleal (muscle) veins

Technique for phlebography of the calf veins Two self fastening rubber tourniquets were applied one just above the ankle and the other just above the knee The ankle tourniquet occludes the superficial veins and directs the contrast medium into the deep venous system The tourniquet above the knee prevents escape of the medium from the calf The fluoroscopic table used for the examination was tilted at least 40 foot downwards so that gravity assisted filling of the calf veins

Between 50 and 100 ml of meglumine iothalamate 60 % was injected into a vein on the dorsum of the foot Films of the calf in both postero-anterior and lateral projections were exposed when the veins were adequately filled as observed on fluoro scopy The tightness of both tourniquets was sometimes adjusted to ensure complete filling

For the p a view the foot was internally rotated to separate the images of the tibia and fibula so that the paired stem veins were not obscured by bone For the lateral view the foot was externally rotated so that the calf lay flat on the table top

Fig 3 a Fig 3 b

Fig 4 a Fig 4 b

Fig 5 a Fig 5 b

Fig 3 a) P a projection Thrombus in the medial peroneal vein (→) b) Lateral view No thrombus in the soleal muscle veins The thrombus in the peroneal vein obscured in this view

Fig 4 a) P a projection b) Lateral projection Recent thrombus in the muscle veins alone in both projections

Fig 5 a) P a projection b) Lateral projection Extensive recent thrombus in both stem and muscle veins visible in both views

A convenient film size was 35 cm × 35 cm split into three Three exposures were made in each projection with sufficient overlap for the veins to be included in at least two of the films

Throughout the examination the patient was instructed not to weight bear contract his muscles or move the leg all of which tend to empty the calf veins After the veins of the calf the more proximal deep veins were examined as previously described (LEA THOMAS 1972)

Results

The posterior tibial veins contained thrombus in 48 (46 6 %) the peroneal veins in 75 (72 8 %) and the anterior tibial veins in 12 (11 65 %) of the examinations

The muscle veins alone contained thrombus in 9 examinations (8 7 %) the stem veins alone in 45 (43 7 %) and thrombus in both the stem and muscle veins in 49 (47 6 %)

Of the cases with thrombus in both stem and muscle veins the thrombus was in continuity between adjacent stem and muscle veins in 24 (49 %) and separately in the stem and muscle veins in 25 (51 %) of the examinations

Discussion

Consistent demonstration of the calf veins has proved especially difficult in the presence of deep vein thrombosis (ALMEN & NYLANDER 1962 DE WEESE & ROGOFF 1959 GREITZ 1955 HALLIDAY 1967 MOORE 1949) However improved demonstration of these veins may be achieved by modifying the standard technique as suggested by NICOLIADES et coll (1971) These authors recommended emptying the muscle veins by the application of an elastocrepe bandage and the use of ankle and above knee tourniquets to trap the contrast medium in the calf They claim to be able to demonstrate the soleal veins in nearly 90 per cent of examinations using their modification It seems however that no phlebographic technique is capable of demonstrating all the vast network of muscle veins in the calf shown by the corrosion cast investigation of COTTON & CLARKE (1965) Other technical improvements which have been used include phlebography carried out in the upright or steep tilt position (MATHIESEN 1958) and exercise phlebography (ALMEN & NYLANDER) KIELY (1973) suggested taking films of the calf when it is relaxed after strong dorsiflexion of the foot This manoeuvre empties the sinusoidal veins so that the contrast medium is less diluted by blood

The present technique for demonstration of the calf veins is similar to that described by NICOLIADES et coll but seems to include significant improvements These improvements are the use of a much larger volume of contrast medium and tilting the examination table steeply f r downwards

The larger amount of medi directed by the tourniquets into the deep venous system displaces the bl u o these veins so that preliminary emptying by bandag

ing or exercise is unnecessary The steep table tilt combined with a tight above knee tourniquet which keeps the contrast medium in the calf demonstrates the muscle veins with the help of gravity and the back pressure effect produced by the tourniquet

By ensuring that the patient keeps the calf muscles relaxed throughout the examination contrast is not expelled by the calf muscle pump (RABINOV & PAULIN 1971)

It is relatively easy to demonstrate the peroneal and posterior tibial veins with the lower leg in the a p or p a view but the anterior tibial veins frequently do not fill in this position (Fig 1 a) In the lateral position with the calf externally rotated the anterior tibial veins are made dependent and invariably fill (Fig 1 b) by gravity because contrast medium is heavier than blood (KJELLBERG 1943)

Many factors influence thrombogenesis an observation summarised by VIRCHOW (1856) when he described his classical triad of the factors leading to thrombosis namely vascular injury decreased flow and changed coagulation conditions These causes of thrombosis are widely accepted today (NILSSON 1971 TILLBERG 1974)

It is well recognised that reduced blood flow is an important factor in thrombogenesis (WESSLER 1972) and this has been confirmed by animal experiments (BORGSTRÖM et coll 1959)

Throughout the venous system it is known that venous stasis occurs in valve sinuses and that thrombus frequently starts here and propagates into the adjacent vein (GIBBS 1959 HADFIELD 1950 HUME et coll 1970 MCLACHLIN 1969 SEVITT & GALLAGHER 1961) It would thus be reasonable to expect thrombus to arise in the stem veins of the calf as it does in other veins In a phlebographic material of 49 legs NICOLIADES et coll (1971) found that in all but one thrombus was present in the soleal veins either alone or in the posterior tibial veins as well These authors concluded that calf vein thrombosis always started in the soleal veins and spread proximally into the posterior tibial veins While thrombus usually arises peripherally and extends proximally this is not always the case as has been shown by phlebography (BROWSE & LEA THOMAS 1974)

In the present series it was found that thrombus was demonstrated in the muscle veins in the majority of examinations (56 3 %) although it was usually in combination with thrombus in the stem veins (Figs 1 5) and only rarely occurred in the muscle veins alone (8 7 % Fig 4) On the other hand in 43 per cent the stem veins *alone contained thrombus (Figs 2 3)*

When adjacent stem and muscle veins contained thrombus in continuity (49 Fig 1 b) no firm conclusion can be drawn as to where the original thrombus started As in the present series a significant number of thrombi were present in the stem veins alone and not in the muscle veins it would have been just as likely for the thrombus to have started proximally in the valve cusp of the stem veins and spread distally into the muscle veins as the converse It is therefore considered that as yet there is no conclusive evidence that the soleal veins are invariably the starting point of venous thrombosis as has been suggested by NICOLIADES et coll (1971)

The findings also indicate that while the peroneal veins and the posterior tibial

veins are the most commonly affected stem veins the anterior tibial veins contain thrombus in a small but significant number of examinations It is therefore important that any phlebographic technique used to demonstrate the calf veins should demonstrate as fully as possible all the stem veins as well as the muscle veins

SUMMARY

A phlebographic technique is described for demonstrating as fully as possible the stem and muscle veins of the calf The findings in 103 examinations containing calf thrombus demonstrated by this method are presented It is concluded that calf vein thrombosis is as likely to originate in stem veins as from the soleal muscle veins

ZUSAMMENFASSUNG

Eine phlebographische Technik wird beschrieben um moglichst vollstandig die venosen Hauptstamme und die Muskelvenen der Wade darzustellen Die Befunde von 103 Untersuchungen bei denen mit dieser Methode Wadenthrombosen nachgewiesen wurden, werden beschrieben Es wird daraus geschlossen dass die Wadenvenenthrombose sowohl vom Venenstamm als auch von den Venen des M soleus entstehen konnen

RESUME

Les auteurs decrivent une technique phlebographique destinée à mettre en évidence aussi complètement que possible les troncs veineux principaux et les veines musculaires du mollet Ils présentent le resultat de 103 examens comprenant des thrombus du mollet mis en evidence par cette méthode Ils concluent que la thrombose des veines du mollet prend probablement son origine aussi bien dans les troncs veineux que dans les veines du muscle soléaire

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INTRA ARTERIAL BOLUS OF [125]I LABELED MEGLUMINE DIATRIZOATE

Early extravascular distribution

P B DEAN and M KORMANO

A selective intra arterial injection of contrast medium as routinely employed in angiography may completely displace blood for several seconds When measured at 5 minutes after injection or later both selective and non selective intra arterial injection have been shown to produce tissue levels of contrast medium similar to those measured after intravenous injection (LAGEMANN 1975 a b 1976) It would seem reasonable to assume that a brief bolus exposure will momentarily cause a rapid blood tissue exchange of the contrast medium The actual tissue concentrations thus reached have not been previously estimated

Following intravenous injection diatrizoate has been shown to spread rapidly through the extravascular (presumably extracellular) spaces of the rat (DEAN & KORMANO 1977 KORMANO & DEAN 1976) The rate of this uptake varied with the tissue type The distribution volume continued to increase up to 5 minutes or later after injection in all tissues examined (muscle fat bone testis skin and subcutaneous tissue) except for bone marrow Tissue concentrations peaked earlier than the distribution volume due to the falling plasma concentration Both tissue concentration and distribution volume should reach maximum values more rapidly after intra arterial bolus injection but it has not been demonstrated whether maximum values are reached during or after the actual passage of the bolus

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The present investigation was undertaken to make direct measurements of the actual tissue concentrations of a contrast medium immediately after intra-aortic injection. Using a double isotope tracer technique with simultaneously injected diatrizoate and albumin, the total tissue diatrizoate concentration as well as the separate intra- and extra-vascular fractions could be calculated. Results were also calculated in terms of the distribution volumes of diatrizoate and albumin.

Materials and Methods

Thirty male rats of the Sprague Dawley strain were placed under intraperitoneal pentabarbitone anesthesia and the abdomen opened with a midline incision. A mixture of ^{125}I labeled meglumine diatrizoate and ^{131}I human serum albumin was injected through a 0.6 mm (external diameter) needle placed directly into the abdominal aorta distal to the renal arteries. After elapsed time intervals of 5, 10, 15, 20, 40 and 120 seconds (5 rats each) the hindlimbs and genitalia were severed with a guillotine and quick frozen in liquid nitrogen while blood samples were taken immediately by cardiac puncture. Dissection of both legs over dry ice proceeded as described previously (DEAN & KORMANO). The injection mixture as well as the calculations were also the same as those previously described. The rat weight ranged from 265 to 450 g, the meglumine diatrizoate dose averaged 24.5 mg/kg (range 15.2 to 35.7 mg/kg) and the actual amount of isotope injected ranged from 7.5 to 21.8 μCi ^{125}I and 5.0 to 10.0 μCi ^{131}I per rat.

Results

Plasma and tissue activity. Plasma albumin activity reached a constant level at 20 seconds, indicating fairly complete mixing of the tracers. The diatrizoate concentration was nearly constant throughout, with only a slight peak at 20 seconds (Fig. 1). Albumin activity in the tissue (not shown) was nearly constant in fat, bone marrow and testis, and declined somewhat over the first 15 to 20 seconds in the remaining tissues. Diatrizoate activity, the uppermost curve in Fig. 2, increased with time in skin, subcutaneous tissue and testis, and remained at a nearly constant level in fat. A temporal fall in activity was found in the remaining tissues.

Tissue space (volume of distribution). Albumin tissue space, representing the relative vascular volume, showed relatively constant values in all tissues after the first 20 seconds (Fig. 2). Diatrizoate space was clearly larger than the albumin space in all the tissues. Due to the nearly constant value of plasma diatrizoate, the tissue diatrizoate space curves (Fig. 2) followed a pattern nearly identical to that described for diatrizoate tissue activity.

Extravascular diatrizoate fraction. The percentage of extravascular diatrizoate in the individual tissues (Fig. 3) rose rapidly to maximum or near maximum levels in

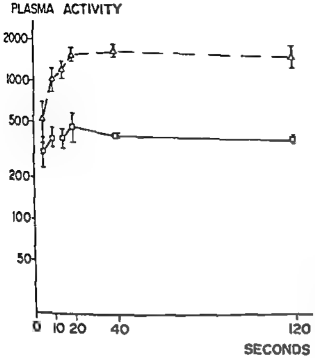

Fig 1 Plasma activity of labeled albumin (△) and diatrizoate (□) in cardiac blood after aortic injection Each point represents the mean ± SEM

15 to 20 seconds in all tissues including the rat as a whole and remained near this level in all tissues measured except bone marrow in which it fell markedly after 40 seconds

Discussion

Intra arterial injection of diatrizoate produced considerably higher initial tissue concentrations (activities) than intravenous injection of an equivalent dose (DEAN & KORMANO) in all tissues measured except the testis During the first 10 seconds after intra arterial injection the tissue concentrations were three to six times higher than the corresponding values following intravenous injection These differences were considerably diminished by 2 minutes and have been shown to have disappeared by 5 minutes (LAGEMANN 1975 b)

A greater extravascular diatrizoate distribution after intra arterial injection was reflected during the first 40 seconds by a plasma diatrizoate concentration considerably lower than that after intravenous injection (KORMANO & DEAN) The diatrizoate distribution volumes of all the tissues examined consisted of much larger extravascular than intravascular fractions from 10 seconds onwards (Fig 3) in all cases more diatrizoate was extravascular after intra arterial than after intravenous injection An interesting deviation from this pattern was the fall in the extravascular fraction of bone marrow diatrizoate at 2 minutes This trend if extrapolated implies

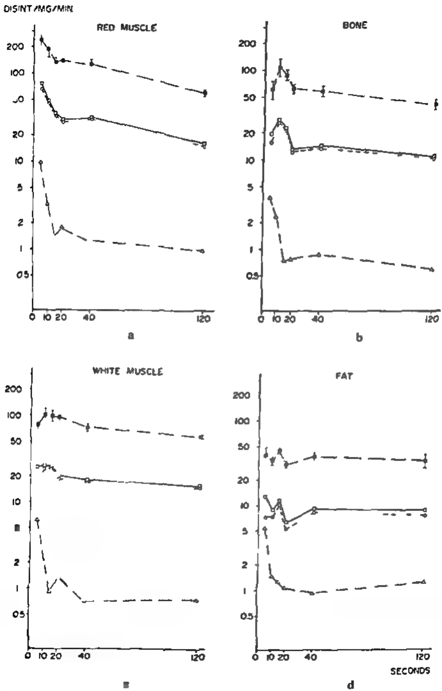

Fig 2 Activity of labeled diatrizoate in disintegrations/mg/min in each tissue after aortic injection is shown as the topmost curve in each graph (■) as mean±SEM The three lower curves in each graph represent total distribution volume of diatrizoate (□) extravascular part of the distribution volume of diatrizoate (○) and albumin distribution volume (△) all three as percentages of total tissue volume

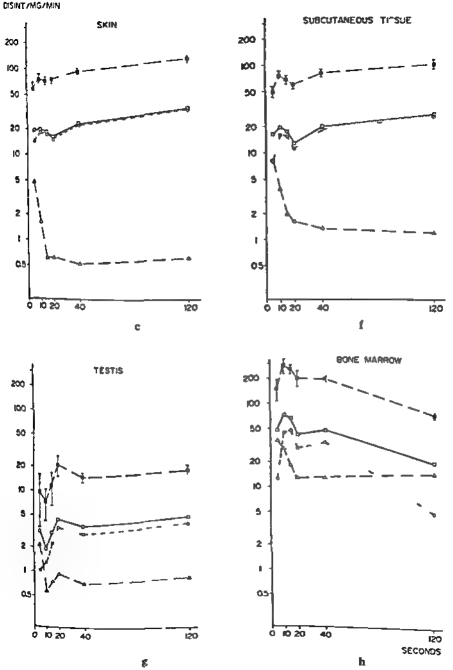

Fig 2 (For legend see opposit page)

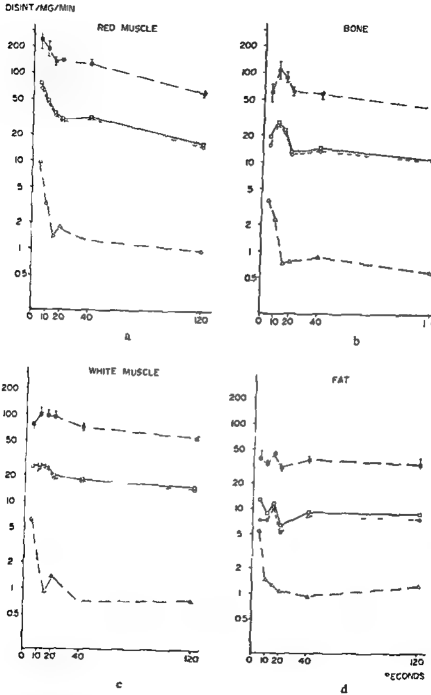

Fig 2 Activity of labeled diatrizoate in disintegrations/mg/min in each tissue after aortic injection is shown as the topmost curve in each graph (■) as mean ± SEM The three lower curves in each graph represent total distribution volume of diatrizoate (□) extravascular part of the distribution volume of diatrizoate (O) and albumin distribution volume (Δ) all three as percentages of total tissue volume

was ess ntially compl te at 5 to 10 s-conds reflecting a readily exchangeable extra vascular spac However in none of th-s tissues except red muscle was maximum diatrizoate distribution volume reach-d this rapidly after intravenous inj-ction and in all but r d muscle and bone marrow it was not reached before 5 minutes (DEAN & KORMANO) The apparent saturation of white muscle bone bone marrow and fat which was rapidly achieved after intra arterial injection was facilitated by the bolus injection This bolus effect was not sufficient to produce maximum concentration nor maximum tissue space of diatrizoate in skin or subcutaneous tissue th- later ris- in thes values may b. attributed to uptake in a second less freely exchangeable extra vascular space possibly transcellular water space such as the lumina of glandular tissue

Averag- curves for the t-stis were similar in both the intra arterial and intravenous ries During th- first 15 s-conds in the intra arterial s-ries approximately half the estes showed no diatrizoate activity as in thes- cases the testicular artery was ap parently proximal to the level of injection

Contrast enhancement in computer tomography has considerable diagnostic potential limited at pres-nt by the lack of understanding of the time course of con rast uptake in individual tissues (KORMANO & DEAN) Higher dos-s of contrast medium will produce greater enhancement but the total dose which can safely be dministered b comes limiting In red muscle the maximum dose reached after intra rterial inj ction exceeds that obtained by intravenous injection but in the other ssu s measured the contrast concentrations reached at 2 to 5 minutes after intra enous inj-ction were of similar magnitude In the lower extremity tissues intra rterial inj ction of a hypotonic dose do.s not appear to produce greater maximum ontrast uptake How ver s-lective and supers-lective injections of hyp rtonic media may produce even greater relative tissue uptake of the medium and hence greater en hancement in for example the abdominal organs Of greatest diagnostic importance ould be enhancement of differential uptake among adjacent tissues and organs Although a great advantage of contrast enhancement at computer tomography is ts non invasiveness patients undergoing angiography could be transferred to a omputer tomograph with the intra arterial catheter still in place for intra arterial ontrast enhancement It would be necessary to us. a short scan time (20 s conds or ss) for such examinations which could become a useful adjuvant to angiography

SUMMARY

A mixture of ^{1} I labeled m glumine diatrizoate and ^{1} ^{1}I labeled human serum albumin was injected into the lower abdominal aorta of 30 anesthetized laparotomized male rats Measurements of the activit es in car liac blood and in different tissues of the hindlimbs and testes were performed at six t me intervals ranging from 5 seconds to 2 minutes after injection the determine early uptake and dist ibution volumes of diatrizoate Concentrations and distribution volumes were initially much greater than values obtained after intravenous injection but these differences nad conside ably decreased or disappeared by 2 minutes

ZUSAMMENFASSUNG

Eine Mischung von [125]I gezeichnetem Meglumin Diatrizoat und [131]I gezeichnetem humanen Serumalbumin wurde in die untere Abdominalaorta von 30 narkotisierten laparotomierten mannlichen Ratten injiziert Die Aktivitaten im Herzblut und in verschiedenen Geweben der hinteren Extremitäten und in den Hoden wurden zu 6 verschiedenen Zeitintervallen zwischen 5 Sekunden und 2 Minuten nach der Injektion gemessen um die fruhzeitige Aufnahme und die Distributionsvolumina von Diatrizoat festzustellen Die Konzentrationen und Distributionsvolumina waren initial wesentlich hoher als die Werte nach intravenoser Injektion diese Unterschiede verminderten sich jedoch wesentlich oder verschwanden nach 2 Minuten

RÉSUMÉ

Un mélange de diatrizoate de méglumine marqué à [125]I et de sérum albumine humaine marqué par [131]I a été injecté dans la partie inférieure de l aorte abdominale de 30 rats mâles anesthésiés et laparotomisés Les mesures des activités dans le sang cardiaque et dans différents tissus des membres postérieurs et des testicules ont été pratiquées à 6 intervalles de temps allant de 5 secondes à 2 minutes après l injection pour determiner la fixation précoce et les volumes de distribution du diatrizoate Les concentrations et les volumes de distribution ont éte au debut beaucoup plus élevés que les valeurs obtenues après injection intraveineuse mais ces différences avaient considérablement diminué ou avaient disparu au bout de 2 minutes

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CIRCULATORY DISTURBANCES FOLLOWING TRANSIENT SOFT TISSUE COMPRESSION TRAUMA

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Previous reports on circulatory changes following trauma to the dog hind leg have shown a transient increase of the flow to the traumatized extremity (LIU 1968 LEWIS & LIM 1970 a b SANDEGÅRD et coll 1974 a LEWIS et coll 1975 a SANDEGÅRD & ZACHRISSON 1975 b) These flow changes imply a reversible loss of vascular tone and an increase in capillary blood flow (LEWIS & LIM RYBECK et coll 1975 b) they are related mainly to the soft tissue injury (SANDEGÅRD & ZACHRISSON 1975 a) The post traumatic increase in flow is also related to a marked dilatation of the larger arteries in the traumatized area (SANDEGÅRD & ZACHRISSON 1975 b LEWIS et coll 1975 b c) The persistent dilatation following multiple contusions to the soft tissue (LEWIS et coll 1975 c SANDEGARD & ZACHRISSON 1975 b) relates to a loss of the contractile function of the vascular smooth muscle caused by an alteration of the ionic distribution in the vessel wall (SANDEGÅRD et coll 1974 c)

A relationship between the haemodynamic changes and the release of energy in the tissue was demonstrated following missile wounding (RYBECK et coll 1975 a BERLIN et coll 1976) However the mechanical component in the transmission of energy responsible for the changes following contusion trauma is still questionable The mechanical changes occurring as a result of the pressure waves released in the tissue by a penetrating missile are similar to a compression or crush injury although the event is very fast (KRAUSS 1957 AMATO et coll 1970 RYBECK et coll 1975 a) Evaluation of contusion trauma with repeated blows to the dog hind leg (LEWIS &

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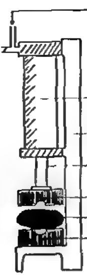

Fig 1 Pneumatic device for production of trauma

LIM LEWIS et coll 1975 c SANDEGÅRD et coll 1974 a SANDEGÅRD & ZACHRISSON 1975 b) gave no exact information as to the amount of energy delivered to the tissue Moreover this experimental set up gave evident macroscopic tissue changes with interstitial bleeding and oedema which per se may alter the flow condition to a certain degree In order to investigate the effect of a single compression on the circulation in the traumatized region a device was designed which produced a single transient compression of the dog hind leg The regional circulation was evaluated by measuring blood flow and by angiography

Material and Methods

Nine dogs of both sexes weighing 16 to 22 kg were anaesthetized with sodium pentobarbital in repeated small doses The trachea was intubated and the dogs breathed spontaneously or were supported by mechanical ventilation

The experimental set up and the operative and radiologic techniques including the evaluation of the films were identical with the procedures described previously (SANDEGÅRD & ZACHRISSON 1975 a b LEWIS et coll 1975 a b)

In 5 animals the blood flow to the extremities was measured with an electromagnetic flow meter (Nycotron Oslo) with the flow probes placed on the external iliac arteries proximal to the deep femoral artery The arterial blood flow was recorded continuously on a Mingograf as well as arterial blood pressure measured by a catheter placed in one carotid artery

Seven animals were examined by serial angiography of the pelvis and the thighs in 3 of these dogs blood flow was measured simultaneously with the angiography For angiography a catheter was introduced through one internal iliac artery a d

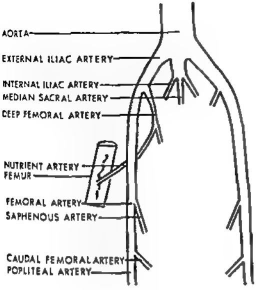

Fig 2 Arteries in the pelvis and hind limb of the dog.

15 ml Isopaque Cerebral (Nyegaard & Co Oslo) was injected manually into the aorta just above the entrance of the external iliac arteries The films were exposed at a rate of 2 films/s for 10 seconds followed by 1 film/s for 10 seconds These animals were examined before trauma 1 2 and 10 min after the trauma Five of the animals were also examined 30 min after the trauma 6 of the animals also 60 and 120 min after the trauma

Trauma Contusion of the soft tissues of one hind leg was produced by blunt compression of short duration The device used consisted of a pneumatic cylinder with a piston attached to a stand Plane jaws measuring 12 cm × 12 cm were fitted on the piston rod and the stand The jaws were recessed corresponding to the place of the femur diaphysis in order to avoid fracture and also to produce an even distribution of the compression to the soft tissues The cylinder and the piston were connected to a compressed air system via a reducing valve (Fig 1) A graded pressure from 0–15 kp/cm² could be applied to the piston In these experiments 15 kp/cm² (1 5 MPa) were used for the trauma As the surface of the piston was 50 cm the device thus delivered a force of 750 kp (7 5 kN) to the thigh The pressure could be switched on or off momentarily In the experiments compression of the soft tissues was limited to 1 to 2 seconds

At the end of the experiments the dogs were killed with an overdose of sodium pentobarbital The tissues were then sectioned and examined macroscopically

Evaluation of angiography and definitions From the film series the transit time of the contrast medium was determined between two defined levels and the diameters of the arteries were measured at corresponding levels

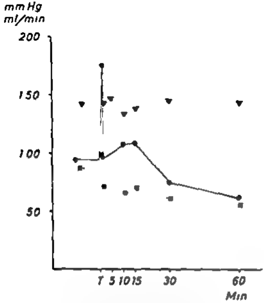

Fig 3

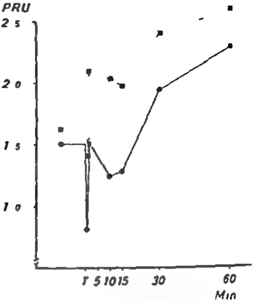

Fig 4

Fig 3 Mean arterial blood flow to the traumatized (●—●) and non traumatized (■ ■) legs (ml/min) and mean arterial blood pressure (▼ ▼) in mmHg before and after a single compression trauma (T) to the hind leg in 5 dogs

Fig 4 Regional resistance to flow (PRU mean values) in the traumatized (●—●) and non traumatized (■ ■) legs before and after a single compression trauma to the hind leg in 5 dogs

All determinations of transit times were related to the same zero level (time 0) which was chosen as the earliest observable filling of the external iliac artery at the origin of the deep femoral artery The transit time of the contrast medium in the femoral arteries was defined as the time difference between zero level and the earliest filling of the caudal femoral artery arising from the distal part of the femoral artery (Fig 2) Arterial filling phase was denoted as the period from zero level to filling of the smallest visible peripheral arteries in the middle part of the thigh in the adductor region In addition the time interval to the earliest filling of the veins was recorded in this region The time of the earliest filling of the distal part of the femoral vein was estimated in an analogous way These latter intervals are referred to in the text as venous appearance times Measurements of the internal diameter of the arteries were performed on the films using a magnifying glass with a built in scale permitting reading to 0 1 mm The magnification factor was 7 The standard error of a single measurement of the external iliac artery was $\pm 0\,07$ mm and of the femoral artery $\pm 0\,05$ mm (SANDEGÅRD & ZACHRISSON 1975 b) Shortening of contrast medium transit time in combination with unchanged or increased diameters or unchanged medium transit time in combination with increased diameters of the vessels was considered as an increase in flow

The course contour and number of the vessels was also considered Extravasation

Table 1

Femoral arterial transit time in seconds (mean and range) at serial angiography in 7 dogs before and after compression trauma

	Before trauma	After trauma				
		1–2 min	*10 min*	*30 min*	*60 min*	*120 min*
Traumatized leg	3 7 (1–6)	2 (1–3)	2 (1–3)	2 3 (1 5–4)	3 3 (1–4 5)	2.8 (1 5–4 5)
Non traumatized leg	3 8 (2–6)	4 (3–6 5)	4 1 (3–6 5)	4 2 (3–5 5)	3 9 (2 5–6 5)	3 6 (2 5–4 5)
No of dogs	7	7	7	5	[illegible]	6

and transient more or less homogeneous accumulation of contrast medium was appraised An accumulation of contrast medium in the tissues during the period of intravascular appearance of contrast medium (vascular phase) was considered to be filling mainly of vessels too small to be defined separately Extravasation of contrast medium was established when the medium remained in the extravascular space after the vascular phase

Results

Haemodynamic measurements Immediately after the trauma a marked increase of the blood flow corresponding to 180 per cent of pretrauma level (mean value) was recorded in the external iliac artery to the traumatized legs of the 5 dogs examined The peak of flow subsided within the first minute after the trauma and was followed by a moderate increase of blood flow within 15 to 20 min after trauma On the non traumatized side the flow was reduced in comparison to that on the traumatized side (Fig 3)

Arterial blood pressure and heart rate fell slightly within the first 5 min after the trauma then returned towards the initial level and remained fairly constant throughout the experiment

Regional resistance to flow (PRU) calculated as the ratio blood pressure blood flow revealed a marked decrease on the traumatized side immediately after the trauma corresponding to the peak increase of flow The PRU then increased and tended to normalize 30 min after the trauma On the non traumatized side PRU increased within the first 15 min after the trauma (Fig 4)

Angiography At the pretrauma examinations no differences or only minor ones were found between the angiographic appearances of the two legs After trauma the transit time of the contrast medium in the femoral artery of the traumatized side was markedly reduced after 1 to 10 min on the average from 4 to 2 s (Table 1) The

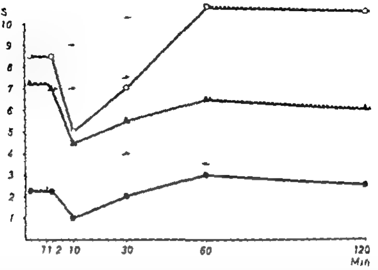

Fig 5 Angiographic transit times of contrast medium in one dog before and after compression trauma (T) to one thigh ▲ Arterial filling phase (arteries of central thigh) ● Femoral arterial transit time ○ Appearance of venous filling (veins of central thigh) — Traumatized leg Non traumatized leg Transit times decreased on the traumatized side especially 10 min after trauma indicating increase of flow

transit time thereafter increased gradually being still slightly reduced 60 and 120 min after trauma in comparison with the pretrauma level and values from the non traumatized side The reduction of femoral arterial transit time was accompanied by a shorter arterial filling phase and earlier filling of veins in the injured region and the femoral vein (Fig 5) Before trauma the arterial filling phase was found to be approximately 6 s and 1 to 10 min following trauma reduced to approximately 4 5 s Before trauma the venous appearance time in the thigh was 9 5 s and that of the distal part of the femoral vein 12 s being reduced following trauma to 5 5 s and 8 5–9 s respectively (Table 2) Later than 10 min after trauma the arterial filling phase and the venous appearance time tended to return to the corresponding pretrauma values

Table 2

Appearance time of contrast medium in the distal part of the femoral vein in seconds (mean and range) at angiography of traumatized leg in 7 dogs before and after compression trauma

	Before trauma	After trauma			
		1–2 min	10 min	30 min	60 min
Traumatized leg	12 (7 5 16)	9 (6 5–14 5)	8 5 (6–12)	11 (7–13)	11 (6 5 16 5)
No of dogs	7		7	5	6

Table 3

Mean angiographic internal arterial diameter (mm) before and after compression trauma in 7 dogs The two distal measuring levels are located within the injured region Traumatized/non traumatized leg

	Before trauma	After trauma				
		1–2 min	10 min	30 min	60 min	120 min
External iliac artery	6 4/6 0	6 4/5 8	6 4/6 0	6 2/5 8	5 9/5 4	5 5/5 2
Femoral artery (at the level of lateral acetabular border)	4 5/4 4	4 4/4 4	4 5/4 5	4 2/4 0	3 8/4 2	3 9/3 9
Femoral artery (1 cm proximal to saphenous artery)	3 9/3 9	4 2/3 9	4 2/4 0	3 7/3 7	3 6/3 5	3 4/3 3
Femoral artery (2 cm proximal to caudal femoral artery)	4 0/4 1	4 4/4 0	4 3/4 1	4 0/3 8	3 9/3 8	3 7/3 7
No of dogs	7	7	7	5	6	6

In the non traumatized leg slightly prolonged or unchanged transit times were found (Table 1)

Significant arterial dilatation was observed in the traumatized region 1 to 10 min after the trauma followed by normalization of the vascular calibre in comparison with the non traumatized leg Measurements of the internal diameter of the femoral artery at two levels within the traumatized region viz 10 mm proximal to the origin of the saphenous artery and 20 mm proximal to the origin of the caudal femoral artery revealed during this period a dilatation of 0 3 mm to 0 4 mm (Table 3) Concomitant with the dilatation of the femoral artery transient dilatation of smaller arteries also occurred Arteries within the traumatized region measuring 1 to 1 5 mm before trauma dilated about 0 5 mm (Fig 6)

Related to these measurable changes of the arterial calibre which appeared simultaneously with the observed shortening of the transit time an increased filling of smaller arteries was observed This was found in the traumatized region especially close to the femur combined with a transient accumulation of contrast medium during the vascular phase (Fig 7) This accumulation was at a maximum 10 min after the trauma and thereafter gradually decreased so as not to be detectable later than [illegible] min after the trauma Early venous filling was a constant finding in the region of accumulation of contrast medium

Apart from slight segmental narrowing of the saphenous artery of the injured side in one dog no vascular constriction was observed

There was no angiographic evidence of morphologic vascular injury in the form of vascular discontinuity or extravasation of contrast medium In no case was displacement of the vessels evident after the trauma

Fig 6 a) Before trauma b) 1 min after compression trauma to right thigh More rapid transit of contrast medium in the traumatized leg compared with the non traumatized side and dilatation of muscular arteries within the injured region (→)

In the non injured leg no vascular changes occurred which could be related to the trauma

Macroscopic examination The trauma produced rapidly disappearing anaemia of the skin and no bleeding or laceration At the end of each experiment the wound region was dissected postmortem No macroscopic abnormalities could be detected in the soft tissues and the large vessels and no thrombosis The trauma did not produce macroscopic injury to the femur

Discussion

A major problem in the initial treatment of trauma patients is the difficulty encountered in the determination of the extent of injury to the tissues Experimental trauma by multiple blows to a large area of the thigh has been used with remarkably reproducible findings (Borgström et coll 1959) However the characteristics of laceration caused by the passage of a bullet may be both a tearing and a compression of the wounded tissues In an attempt to isolate the compression effect an experimental set up was designed to enable the application of a constant pressure in every experiment The consequences of the wounding ability were recorded as changes in regional circulation at angiography and as measured by electromagnetic flow meter

In the angiographic estimation of circulatory changes the flow increasing effect

a b c

d

Fig 7 Angiography 1 min after compression trauma to the thigh a) 2 5 s b) 5 s c) 6 s and d) 10 5 s after zero level (time 0) Transient homogeneous accumulation of contrast medium in central part of thigh (b–c) combined with early venous filling (→) indicating increase of flow After 10 5 s no accumulation ar only veins filled (d)

of the contrast medium must be considered (LINDGREN & TÖRNELL 1958 BOIJSEN et coll 1971) LEWIS et coll (1975 a) have shown that also after soft tissue trauma, the informative arterial phase appears in the time lag between injection and the flow increasing effect of the contrast medium and furthermore found no evidence of a cumulative effect of the contrast medium The effects of the contrast medium itself may be disregarded as the experimental set up also implied comparison of the traumatized and non traumatized leg in each animal

The measurement of blood flow as well as angiography by determining contrast medium transit time and diameter of the vessels during comparable periods of time accordingly demonstrated a transient increase in flow to the traumatized extremity immediately after the trauma

The marked increase of flow following within one minute after trauma as recorded on the flow curve had a character similar to that recorded following missile wounding (LEWIS et coll 1975 b) This increase of flow caused by a decrease of regional resistance to flow points to a transient release of precapillary tone The similar but more rapid change in regional flow was considered to be produced by the shock wave in missile wounding This mechanism might be operative also after compression trauma

The origin of the changes in flow observed later than one minute after the compression trauma was not revealed by this experiment A mechanism analogous to that proposed by SANDEGÅRD et coll (1974 a, b) with release of vasodilator substances in the injured ar a might be suggested

The electromagnetic flow meter data gave an appreciation of the total changes of flow in the traumatized extremity At angiography it was possible to differentiate these changes Increased flow was thus apparent in the injured region especially adjacent to the femoral bone by dilatation of the vessels in addition to transient accumulation of contrast medium followed by early venous filling The accumulation of contrast medium during the vascular phase thus suggested an increase in capillary flow in the traumatized area This finding is in agreement with previous angiographic observations of multiple blow contusion injury (SANDEGÅRD & ZACHRISSON 1975 b) and missile wounding (LEWIS et coll 1975 b) The transient changes in flow regionally and locally in the traumatized region in addition to lack of angiographic and macroscopic inspection evidence of injury to larger vessels point to a discrete trauma despite release of a great amount of energy This is further underlined by the fact that the arterial dilatation did not persist throughout the experiments as previously reported in soft tissue trauma (SANDEGÅRD & ZACHRISSON 1975 b LEWIS et coll 1975 c)

The present investigation furthermore emphasizes the significance of injury to soft tissue in trauma it is apparent that the existence of haemodynamic changes following trauma does not necessarily involve macroscopically demonstrable injury

It remains to be investigated whether a greater amount of energy release produces

a more marked haemodynamic response The changes in regional and local haemodynamics following trauma did not seem to be elicited in an all-or none manner

The use of graded transient pneumatic compression is one possible method for the evaluation of haemodynamic changes following trauma to the extremity of the dog

Acknowledgements

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SUMMARY

Circulatory changes following standardized compression trauma to the hind leg in dogs were evaluated using an electromagnetic flow meter and repeated angiography A transient increase of flow to the injured limb and within the traumatized region was observed Good agreement was found between the electromagnetic flow recordings and estimates of relative changes in flow by the angiographic method

ZUSAMMENFASSUNG

Die zirkulatorischen Veranderungen nach einem standardisierten Kompressionstrauma der hinteren Extremitat von Hunden wurden unter Verwendung einer elektromagnetischen Durchblutungs-Messausrüstung und wiederholter Angiographie festgestellt Ein vorubergehender Anstieg der Durchblutung der geschadigten Extremitat und innerhalb der traumatisierten Region wurde gefunden Eine gute Übereinstimmung wurde zwischen den elektromagnetischen Durchblutungsmessungen und den berechneten relativen Veranderungen der Durchblutung mit der angiographischen Methode gefunden

RESUME

Les perturbations circulatoires après traumatisme par compression standardise de la patte posterieure de chiens ont ete étudiees au moyen d un debitmètre électromagnetique et d angiographies repetees Les auteurs ont observe une augmentation transitoire du debit dans le membre lese et dans la region traumatisee Ils ont trouve une bonne concordance entre les mesures électromagnetiques du débit et les estimations des modifications relatives du débit par la methode angiographique

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APPEARANCE OF THE RIGHT CORONARY SULCUS AT CONVENTIONAL ROENTGEN EXAMINATION OF THE HEART

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Occasionally a vertically oriented narrow band of slightly diminished attenuation can be observed on the lateral image of the heart (Figs 1–3) just in front of the lowermost part of the anterior wall of the ascending aorta descending downwards against the diaphragm The occurrence and significance of this finding has not to our knowledge been previously described in the radiologic literature

Material and Methods

Twenty one adult patients in whom this structure was observed on conventional chest films subsequently underwent cineangiography of the heart The contrast medium was selectively injected into either the left ventricle ascending aorta or coronary arteries Four additional patients underwent cardiac fluoroscopy with a TV chain Further the coronary angiograms of 45 other patients were re-examined for the estimation of the frequency with which this structure appears on the lateral view of the heart before contrast injection

The lateral films at the conventional roentgen examination were obtained at 170 to 200 kV tube potential and at a film focus distance of 2 m Kodak RP/L films were exposed between Kodak X omatic screens and developed in RP MX 810 at 35 5 C processing time 90 s Generally exposure times varied between 10 and 30 ms The

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Fig 1 Various appearances of the right coronary sulcus

angiography was recorded on 35 mm cine film utilising a Philips bi plane equipment with 23 13 cm (9 5) cesium iodide activated image intensifier Lateral view of the heart was always included Exposure time was 3 ms The same equipment as for angiography was used for fluoroscopy

Results

On the lateral chest film a narrow band like structure of somewhat diminished attenuation could be observed extending from the area just anteriorly to the lower most part of the ascending aorta (BERGSTRAND & SZAMOSI 1976) downwards against the diaphragm It was always vertically oriented sometimes with a gentle posterior slope or slight anteriorly convex curvature (Figs 1–3) In 3 patients this structure appeared as a borderline between two more homogeneous areas within the outlines of the heart where the area anteriorly appeared to have a somewhat lower attenua tion (Fig 3) In whichever form it could always be identified as the right coronary sulcus either on the cine film or at fluoroscopy The identification was based on the characteristic movements a rapid anterior shift from an intermediate position during each ventricular systole preceded by a shorter posterior displacement during atrial systole In those 21 cases where angiography was performed the contrast filled right coronary artery was always seen to run parallel and just in front of the described structure closely following its movements In one of the cases without angiography extensive calcifications were seen in the wall of the coronary artery in the same posi tion displaying the same movements (Fig 2) The result of the turning of the pa tients under fluoroscopy was always consistent with the findings described

Fig 2

Fig 3

Fig. 2. Calcifications in the wall of the coronary artery in the upper part of the coronary sulcus (→ low contrast due to approximately 180 kV)

Fig. 3 The coronary sulcus is closely following the anterior border of the right atrium (tricuspid insufficiency)

Of the 45 coronary angiograms re-examined the right coronary sulcus could be obs rved in 37 (82 %) before injection of the contrast medium into the right coronary artery

Discussion

The name right coronary sulcus (KOPSCH 1955) denotes the deep furrow between the right atrium and ventricle as seen from outside after the opening of the peri cardial sac It lies somewhat to the right anteriorly and inferiorly to the ascending aorta The right coronary artery runs in this groove at somewhat variable depth Loose fatty tissue—an extension of the epicardial fat—is usually present in the sulcus filling the space around the coronary vessels It is conceivable that this tissue or the borderline between it and the anterior wall of the right atrium under favourable circumstances is visible BERGSTRAND & SZAMOSI (1976) pointed out small local differences in the attenuation of roentgen rays which may be present within the peri cardial sac and which are usually but not always blurred out by the constant rapid movements of the heart They found parts of the intrapericardiac segment of the ascending aorta visible on conventional chest films in about 50 per cent of the cases With cine technique the exposure time is usually short and the movements of the

heart—contrary to the case at conventional examination—enhances the perception of small differences in attenuation when these are arranged in an orderly manner corresponding to well known anatomic structures

As the right coronary artery—contrary to the left circumflex—runs closely related to the corresponding sulcus the position of the sulcus indicates the position of the artery Thus the observation of the sulcus makes easier the perception and identification of calcifications in the right coronary artery Further for obvious anatomic reasons the sulcus marks the outer half circumference of the right fibrous annulus which connects the right ventricle and atrium Because of the varying overlap between these chambers as seen on the lateral view the tricuspid valve will appear somewhat posteriorly to the sulcus The amount of overlap depends partly on the rotational position of the heart and partly on the relative width of the right atrium and ventricle with respect to the diameter of the fibrous annulus The apparent distance in the sagittal plane between the right coronary sulcus and the anterior wall of the lowermost part of the ascending aorta will be influenced by the size of the fibrous annulus as well as the rotational position of the heart around the vertical axis Consequently the position of the right coronary sulcus and its relation to the ascending aorta does not indicate the relative or absolute size of the right sided heart chambers However the distance between the inferior vena cava and right coronary sulcus as seen on the lateral view of the heart may in some way be indicative of right atrial size The clinical exploration of this possibility must await further collection of data

SUMMARY

The appearance of the right coronary sulcus on the lateral films at conventional radiologic examination of the heart is described The explanation and possible diagnostic implications of this finding are discussed

ZUSAMMENFASSUNG

Das Aussehen der rechten Kranzfurche auf Seitenbildern bei gewohnlicher Rontgenuntersuchung des Herzens wird beschrieben Die Deutung und die moglichen diagnostischen Folgen dieser Beobachtung werden diskutiert

RESUMÉ

Les auteurs décrivent l aspect du sillon coronaire droit sur les films de profil de l examen radiographique simple du cœur Ils examinent l explication et les conséquences diagnostiques possibles de ce signe

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RADIOLOGY AND LARYNGOSCOPY FOR THE DIAGNOSIS OF LARYNGEAL CARCINOMA

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Although the larynx is accessible to direct inspection and palpation radiologic examination is considered indispensable for determining the extension of tumors of this organ The methods most commonly used are conventional films tomography and laryngography with positive contrast medium

In an attempt to throw light upon the question whether all these radiologic methods really are necessary in all patients a prospective investigation was performed The findings yielded by conventional films tomography and laryngography were compared with the clinical findings obtained with indirect laryngoscopy and direct laryngoscopy using the operating microscope (microlaryngoscopy)

Radiology was used by SCHEIER (1899 1901–1902) particularly to demonstrate the ossification of the laryngeal cartilages and by THOST (1913) for examining the pathology of the larynx COUTARD (1924) considered that radiology was useful in deciding the mode of treatment for laryngeal carcinoma. Important advances in laryngeal radiology were made by BACLESSE (1949) who introduced the high voltage technique with heavy filtration This technique has the advantage of short exposure time and minimal superimposition of skeletal structures (MAGUIRE et coll 1965 MAGUIRE 1966 HEMMINGSSON 1972 b) It is in use at many centers (POWERS et coll 1957 THORNBURY & LATOURETTE 1967)

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The microlaryngoscopic technique which was introduced by KLEINSASSER (1968) may be combined with inspection using regular laryngoscopes and 90 optical instruments to provide a more accurate examination procedure Microlaryngoscopy is useful for photographic documentation which enables a more exact comparison with the radiologic findings to be achieved

Material and Methods

The case series comprised most patients treated for laryngeal carcinoma over a 3 year period (October 1971 to October 1974) at this hospital

Patients with superficial glottic lesions in whom an invasive carcinoma was not clinically suggested before direct laryngoscopy were not included In one patient who was 85 years of age laryngography was not performed No patients were excluded from the material because the examinations were evaluated as unsatisfactory nor was laryngography omitted in patients with large carcinomas and a narrow airway After these exclusions 51 patients remained 48 men and 3 women Their ages ranged from 42 to 77 years with a mean of 65 years

Forty four carcinomas were classified as primary glottic 6 supraglottic and 1 subglottic Three patients had recurrent tumors more than one year after previous radiation therapy by this time the post irradiation edema would have largely subsided All the other patients were examined before any kind of therapy

In order to avoid edema which may lead to errors in the evaluation of the condition all radiologic examinations were performed before biopsy In those few patients referred from other hospitals where biopsies had been performed an interval of at least one week had passed between the biopsy and the radiologic examination and the repeat laryngoscopy In nearly all patients the clinical and radiologic examinations were performed by the authors

Examination procedure A tentative diagnosis of laryngeal carcinoma was made by mirror laryngoscopy The patient was then submitted to radiology including conventional films tomography and laryngography Direct laryngoscopy was then performed using an operating microscope (microlaryngoscopy) When all the data had been collected the radiologic and clinical findings were compared in detail The radiologist recording his findings was unaware of the results of the laryngoscopy

Conventional films A high voltage technique (135 to 150 kV) with 1 mm Cu filtration was employed FFD was 140 cm and high resolution screens were used Exposures were made during quiet inspiration phonation inspiratory phonation and the Valsalva manoeuvre (expiration against closed lips and nose) One lateral view was exposed at 70 kV in order to examine the ossification of the laryngeal cartilages

Tomography Anteroposterior tomography with linear motion parallel to the longitudinal axis of the neck was carried out with the patient supine A Massiot–Philips polytome was employed The exposure angle was 30 and the exposure time 0 32 s The tube potential was 70 to 90 kV and a multi section cassette designed for this potential was used Exposures were made during quiet inspiration and phonation

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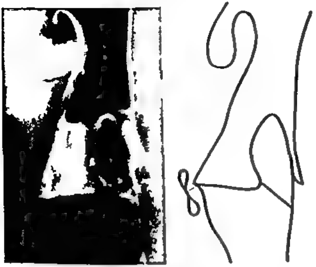


a b

Fig 2 Laryngography lateral view The bulging in and below the anterior commissure (hatched area) normally does not exceed 5 mm

Table 1

Involvement of the anterior commissure Glottic carcinoma 44

	Conventional films	Laryngography
Demonstrated clinically 16 (?)		
No of examinations	16	16
Involvement demonstrated	4 (1)*	15 (3)
Not demonstrated clinically 28		
No of examinations	28	28
Involvement demonstrated (false positive)	0	4 (4)*

Patients with probable positive findings included in the preceding figure

region and the laryngeal ventricles Tumors confined to one vocal cord were also evaluated The radiologic findings were checked against the observations yielded by laryngoscopy The results are presented in Tables 1 to 3 The values presented include certain and probable findings the latter in parentheses

Anterior commissure involvement (*Table 1 Figs 2 3 4*) None of the primary subglottic or supraglottic tumors involved the anterior commissure as estimated from the radiologic or laryngoscopic findings

The normal lateral laryngogram exposed during inspiration usually demonstrates a slight dorsal bulging of the soft tissues not exceeding 5 mm in and below the anterior commissure (Fig 2) When the anterior commissure was involved by tumor

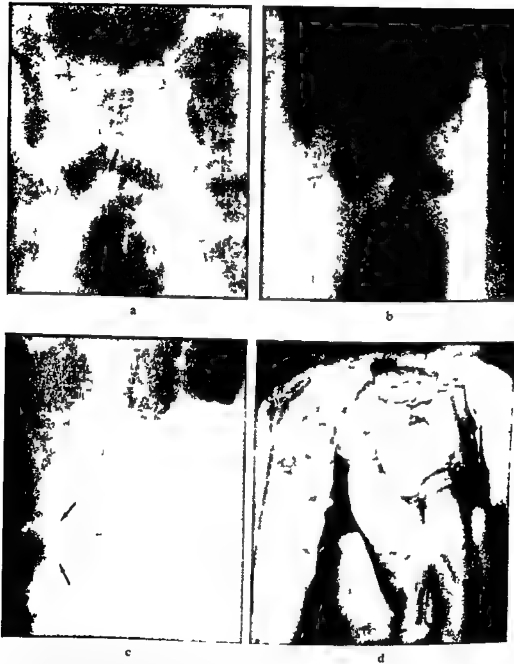


Fig. 3 Glottic carcinoma with involvement of th anterior commissure visible at laryngography and well correlated to the microlaryngoscopic finding. a) Conventional p a view b) Tomography c) Laryngography Lateral view Arrows indicate tumor d) Microlaryngoscopy Grayish white ulcerated tumor occupying the anterior one third of the right vocal cord the anterior commissure and a few mm of the left vocal cord The free margin of the right vocal cord has been turned upwards by the tip of the suction tube to show the subglottic extension in the anterior commissure

a

c

Fig. 6 [illegible] the [illegible] ment of exter[illegible] view [illegible] by [illegible] ex[illegible] strat[illegible] Subglottic scopy [illegible] anterior [illegible] and [illegible] vocal cord hidden [illegible] which [illegible] vocal cord.

Table 2

Subglottic involvement Glottic carcinoma 44 Subglottic carcinoma 1

	Conventional films	Tomography	Laryngography
Demonstrated clinically 23 (1)* **			
No of examinations	23	22	23
Involvement demonstrated	16 (1)*	17	23
Not demonstrated clinically 22			
No of examinations	22	18	22
Involvement demonstrated (false positive)	3	1	3

* Patients with probable positive findings included in the preceding figure

** Tomography was not performed in this patient

this bulging was more prominent and the mucosa usually irregular An evaluation of the anterior commissure can be conducted by means of conventional films and laryngography but not by a p tomography On a lateral film the anterior part of the thyroid cartilage forms a figure of 8 distortion of which suggests cartilage invasion (OLOFSSON et coll 1975)

Anterior commissure involvement was demonstrated clinically in 14 patients with certainty and probably in a further 2 Laryngography demonstrated involvement in 15 patients and conventional films in 4 with very large carcinomas

According to the clinical examination the anterior commissure was uninvolved in 28 patients Laryngography indicated probable involvement in 4 of these patients

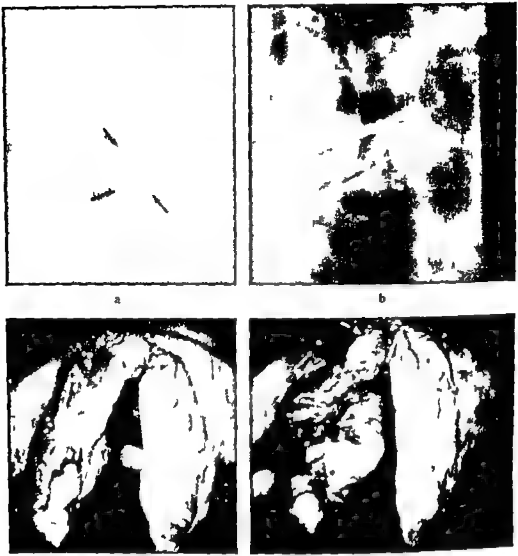
Subglottic involvement (Table 2 Figs 5 6 7) None of the supraglottic tumors involved the subglottic region

Laryngoscopy showed involvement in 23 patients All 3 radiologic methods demonstrated involvement in 14 patients laryngography and conventional films in another 2 laryngography and tomography in another 3 and laryngography alone in the remaining 4 patients in whom the subglottic extension was confined to the under surface of the cord not blunting the subglottic angle

In 3 patients conventional films and laryngography suggested subglottic tumor extension and so did tomography in one of them but neither could be confirmed clinically

Fig. 5 Glottic tumor with extension to the under surface of the vocal cord a) Conventional film p a view b) Tomography p a view c) Laryngography p a view Phonation d) Laryngography p a view Inspiration Arrows indicate tumor e f) Microlaryngoscopy Exophytic ulcerated tumor occupying the free margin of the right vocal cord with subglottic extension (f) where the free margin of the right vocal cord has been turned upwards The slight subglottic extension to the under surface of the vocal cord is only assessable by laryngography In (a) and (b) only a slight swelling of the right vocal cord is demonstrated

Fig 5 (For legend see opposite page)



a b c d

Fig 6 Glottic carcinoma with subglottic extension a) Conventional film p a view b) Laryngography p a view Arrows indicate tumor c d) Microlaryngoscopy Ulcerated tumor occupying the full length of the left vocal cord extending subglottically (d) where the under surface of the vocal cord has been turned upwards with the tip of the suction tube The subglottic extension is clearly visible in both (a) and (b) but the upper part of the tumor is better demonstrated in (b)

Involvement of the laryngeal ventricles (*Table 3 Fig 7*) On conventional films and tomograms the ventricles were considered to be unaffected by tumor when they were partially and symmetrically filled with air Asymmetrical partial filling was taken as evidence of invasion Bilateral absence of air filling precludes any evaluation This finding has been recorded as probable involvement in Table 3 and was present

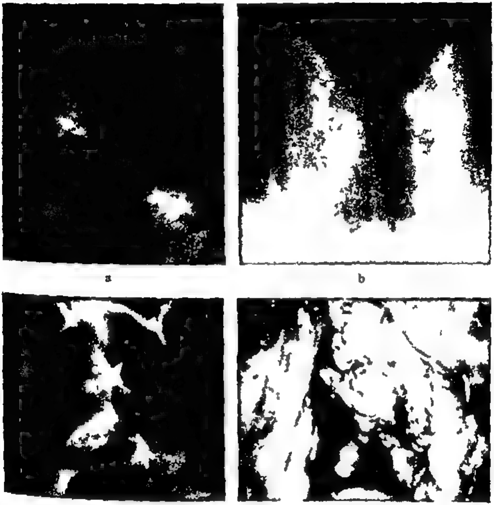


Fig 7 Glottic tumor with sub- and supraglottic extension a) Conventional film p a view b) Tomography a p view c) Laryngography p a view Arrows indicate tumor d) Microlaryngoscopy The keratinized exophytic tumor occupies the full length of the right vocal cord with sub- and supra glottic extension Superficial infiltration of the left vocal cord The less severely affected side was without visible involvement at radiology

in the tomograms of 11 patients laryngoscopy indicated involvement in only 2 of them

Ventricular involvement was demonstrated clinically in 19 patients In 3 of these bilateral ventricular involvement was clinically evident whereas the radiology demonstrated abnormalities on one side only

In one patient with glottic carcinoma the conventional films tomography and laryngography suggested ventricular involvement that could not be confirmed clinically

Table 3

Involvement of the ventricles Glottic carcinoma 44 Supraglottic carcinoma 6 Subglottic carcinoma 1

		Glottic	Supra glottic	Sub glottic	Total
Demonstrated clinically		16	2	1	19
Conventional films	No of examinations	16	2	1	19
	Involvement demonstrated	14 (4)	2	1 (1)	17 (5)
Tomography	No of examinations	13	0	1	14
	Involvement demonstrated	12 (2)		1 (1)	13 (3)*
Laryngography	No of examinations	16	2	1	19
	Involvement demonstrated	14 (1)*	2	1	17 (1)
Not demonstrated clinically		28	4	0	32
Conventional films	No of examinations	28	4		32
	Involvement demonstrated (false positive)	2 (2)*	1 (1)*		3 (3)*
Tomography	No of examinations	26	4		30
	Involvement demonstrated (false positive)	10 (9)*	0		10 (9)*
Laryngography	No of examination	28	4		32
	Involvement demonstrated (false positive)	1 (1)*	2 (2)*		3 (3)

* Patient with [illegible] positive findings included in the preceding figure

In 4 of the 6 patients with primary supraglottic tumors laryngoscopy showed no involvement of the ventricles In one of these the conventional films and in another 2 the laryngograms did suggest such involvement

Tumors localized to one vocal cord The clinical examination in 13 patients disclosed glottic carcinoma confined to one vocal cord Nine of these were demonstrated on conventional films 8 on tomograms and 11 on laryngogram (in one of the patients tomography was not performed) In 2 patients with superficial tumor growth laryngography was estimated as normal These tumors were not observed on either conventional films or tomogram Conventional films and tomography failed to reveal another 3 tumors one at both and the other 2 on either examination In addition tomography suggested sub- or supraglottic extension of 3 tumors that was not demonstrated clinically or by any of the other examination methods

Discussion

Involvement of the anterior commissure the subglottic region and the ventricles has important implications for classification and prognosis and for treatment planning

Fig. 8 Supraglottic tumor occupying the right false vocal cord a) Tomography a p view b) Laryngography p a view Arrows indicate tumor c d) Microlaryngoscopy Exophytic tumor occupying the full length of the right false vocal cord (c) vocal cords normal (d) Tomography yields as much information as laryngography The inner lower angle of the ventricle was uninvolved by the tumor

In the region of the anterior commissure there is a great risk of invasion of the thyroid cartilage mainly because of the close proximity of the mucosa to the cartilage with no intervening muscle tissue Glottic carcinomas that cross the anterior commissure may easily spread subglottically into the anterior subglottic space and then there is a risk of further spread outside the larynx through the cricothyroid membrane (OLOFSSON et coll 1972 OLOFSSON & VAN NOSTRAND 1973)

Involvement of the anterior commissure was observed only in patients with glottic carcinoma (Figs 3 4) In the case of such tumors mucosal involvement is usually detected by laryngoscopy Additional information may be obtained with a 90

involvement of the less severely affected side may easily be overlooked in a radiologic examination (Fig 7 OLOFSSON et coll 1973)

This material consisted mainly of primary glottic tumors including many small ones which are better evaluated and photographically documented by microlaryngoscopy than are large supraglottic tumors and only in a few of these small tumors did the radiologic examinations add important information to the clinical evaluation JÖRGENSEN et coll (1975) made the same observation However in many patients especially those with larger carcinomas radiology and the clinical examination supplement each other Laryngography was found to be superior to conventional films and tomography As a rule a conventional film exposed with high tube potential and heavy filtration was more informative than tomography with low potential and a 30 exposure angle In the present material tomography added no information to that obtained with laryngography However it should be mentioned that the possible merits of tomography in demonstrating cartilage destruction have not been considered A lateral film of the larynx exposed with low tube potential would seem to be better in this respect than a p tomography (JING)

Cases of bronchopneumonia as a sequela to bronchography have been reported but this condition seems to develop only after marked alveolar filling (RAYL & SPJUT NELSON et coll) In none of the present 51 patients was this complication encountered However another patient an elderly woman with a benign lesion and chronic bronchitis did develop slight transient bronchopneumonia Incidentally this was the only complication noticed in some 150 laryngographies

To compare the relative merits of different radiologic procedures is a difficult task and some bias is probably inevitable The fact that all films of a particular patient were reviewed on the same occasion implies a risk that the findings at one examination influenced the evaluation of the other examinations The present diagnostic routine includes the liberal use of conventional films in contrast to static tomograms but in common with laryngograms these afford the opportunity for a dynamic examination Conventional roentgen examination is easily accomplished as a preliminary procedure immediately before laryngography which is performed in all patients with a possible malignant tumor

Neither the radiologic nor the clinical examination methods tell the whole truth about the tumor extension but they are complementary In this center most patients with laryngeal carcinoma are treated by primary irradiation However laryngectomy is carried out in patients with large tumors usually following preoperative radiation therapy

In an investigation at present being conducted the clinical and radiologic findings are being compared with the macroscopic and microscopic observations using the technique of whole organ serial sectioning

Conclusions

1 The use of radiologic methods of examination is mandatory in the diagnosis and classification of laryngeal carcinoma

2 The radiologic examinations should be performed before laryngoscopy and biopsy so as to avoid the possibility of interfering edema

3 Laryngography with positive contrast medium is superior to conventional films and tomography

Acknowledgements

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SUMMARY

A comparison is made of the radiologic and clinical findings in 51 patients with laryngeal carcinoma The radiologic methods comprised conventional films tomography and laryngography the clinical examination technique included microlaryngoscopy and the use of a 90 optical instrument Laryngography was found to be superior to the other two radiologic methods for the delineation of the tumors Radiology should be performed before laryngoscopy and biopsy

ZUSAMMENFASSUNG

Die radiologischen und klinischen Befunde von 51 Patienten mit einem Kehlkopfkarzinom werden verglichen Die radiologischen Methoden umfassten konventionelle Filme Tomographie und Laryngographie die klinische Untersuchung umfasste eine microlaryngoskopische Technik und die Verwendung eines 90 optischen Instruments Die Laryngographie erwiess sich als uberlegen uber die anderen zwei rontgenologischen Methoden zur Abgrenzung des Tumors Die Rontgenuntersuchung sollte vor der Laryngoskopie und der Biopsie ausgefuhrt werden

RESUME

Les auteurs ont compare les signes radiologiques et les signes cliniques chez 51 malades atteints de carcinome du larynx Les methodes radiologiques utilisées ont éte les films simples la tomographie et la laryngographie La technique d examen clinique a compris la microlaryngoscopie et l utilisation d un instrument avec une optique a 90 La laryngographie a éte superieure aux deux autres methodes radiologiques pour la délimitation des tumeurs La radiologie devrait etre faite avant la laryngoscopie et la biopsie

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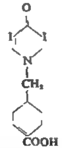
FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY UNIVERSITY HOSPITAL S 221 85 LUND SWEDEN

PRECIPITATION OF A CHOLEGRAPHIC CONTRAST MEDIUM IN A DOG

TORD OLIN

A gallstone developed in a dog after administration of one of several contrast agents based on the diodrast molecule and intended for intravenous cholegraphy

Chemically the agent was composed of iopydone linked to benzoic acid in the paraposition [Ω (3 5 diiodo-4-pyridone) N p-toluyl acid] (supplied by Leo Sweden)



The molecular weight of the acid was 481 and its iodine content 43 2 per cent A solution containing 12 2 per cent of the diethanolamine salt equal to 10 per cent acid was used in the experiments LD 50 at acute intravenous injection in rats was about 1 400 mg acid/kg body weight Ten rats with a body weight of about 200 g were given 122 mg diethanolamine salt subcutaneously The animals were usually inactive and two died after 5 and 7 days respectively True albuminuria was present in all cases Pseudoalbuminuria due to the contrast medium per se also occurred

Submitted for publication August 1976

a b

a) Intravenous cholegraphy Lateral projection Stone in the gallbladder b) Conventional film of the abdomen two weeks later The stone remains

Cutaneous necrosis developed at the injection sites but were never large Microscopy post mortem revealed degenerative changes in the kidney and precipitation of calcium compounds in the tubules Nothing abnormal was noticed in the liver the rat has no gallbladder The choleretic effect was analysed in a cat under general anaesthesia The cystic duct was ligated and the common bile duct cannulated as was the carotid artery Following injection of the diethanolamine salt (160 mg/kg body weight) bile production increased to three to four times the basal value The choleretic effect began to diminish after about half an hour and the arterial blood pressure and pulse were unaffected

A 10 kg mongrel dog was examined weekly with doses increasing from 50 to 100 mg salt/kg body weight A dose of 100 mg/kg gave relatively good filling of the gall bladder and the bile duct 30 to 60 min after the injection Some excretion in the kidneys was also observed At the next injection one week later the dog was given 150 mg salt/kg body weight The gallbladder was filled with well concentrated contrast medium but at a repeat examination one week later an abnormality suggestive of a stone measuring 10 mm × 15 mm had developed in the gallbladder The stone had a greater attenuation than bone (Figure) Repeat examinations during the following 5 weeks revealed that the stone became somewhat more compact although otherwise it did not change The dog was cholecystectomized 6 weeks after the injection The stone consisted of a thick tar like green black mass containing iodine No inflammatory lesions were seen in the gallbladder

Discussion

The deposition of calcium crystals in the rat kidney might indicate that the solubility of the calcium salt of the contrast medium is low A solution of calcium salt of the medium is saturated at a concentration of 1 16 mM at pH 6 4 and 37 C

Its solubility coefficient $c_s = [Ca^{2+}] \times [\text{contrast medium}^{-1}]$ was calculated to be 6.27×10^{-9} M³ The solubility of the acid is even lower and amounts to 8.3×10^{-6} M at 37 C i e it is almost insoluble The relatively good attenuation of the medium within the bile ducts and the gallbladder indicate a high iodine concentration of a magnitude of several mg I/ml The reason why no precipitation appeared in the gallbladder at dose levels below 150 mg salt/kg body weight is probably due to bio transformation of the contrast medium Contrast media mainly excreted in the bile are often conjugated with glucuronic acid in the liver (McCHESNEY & HOPPE 1954 1956) The amount of free non conjugated contrast acid in bile and urine would then be quite low and the fluids not oversaturated The fact that calcium crystals were found in the tubules of the kidney does not necessarily mean that they consist of calcium salt of the contrast acid It is a well known phenomenon that calcium oxalate easily will precipitate in the urine on a seed e g a catheter or a suture

Some other media for cholecystography also have low solubility Thus the solubility of iopanoic acid (Telepaque Winthrop) is only 0.4 mM at pH 6.5 (McCHESNEY & BANKS 1965) and that of its calcium salt is 1.74 mM Precipitation of contrast agent in the gallbladder (THEANDER 1955) has been observed following ingestion of iopanoic acid Renal injury has also been reported (RENE & MELLINKOFF 1959 CANALES et coll 1969) and in one case with a fatal outcome (WENNBERG et coll 1963) precipitation of calcium salt crystals occurred in the kidney Conjugation with glucuronic acid is probably of decisive importance for whether or not contrast medium precipitates Diminished conjugation might occur when hepatic function is impaired e g due to biliary or toxic agents such as carbon tetrachloride (this was probably the case in one of the patients of RENE & MELLINKOFF) Conjugated iopanoic acid is hydrolyzed in the presence of β glucuronidase (LASSER 1966) This enzyme exists as granulae in the mucosa of the gallbladder (LASSER & SAUNDERS 1965) as well as in the epithelium of the urinary tract A relatively large amount of the enzyme is found in the urinary bladder but much less in the kidneys (BOYLAND et coll 1955) so that deconjugation is less likely to occur in the latter Increased diuresis at cholecystography to prevent crystalluria has been recommended (NELSON 1963) Liberation of β glucuronidase may well occur in the gallbladder in pathologic conditions such as cholecystitis and might have been the reason for precipitation of gallstone in the case described by THEANDER

Another medium for cholecystography with low solubility was bunamiodyl (Orabilex) which due to its nephrotoxicity was withdrawn from the market HARROW & SLOANE (1965) described an interesting phenomenon following cholecystography with 6 g of this drug One day after the ingestion of the drug urography revealed a moderate nephrographic effect bilaterally It was assigned to toxic action of the cholecystographic medium on the renal blood vessels A much more plausible explanation is widespread precipitation of the cholecystographic medium in the tubules with subsequent intrarenal urine stasis

SUMMARY

Following intravenous injection of a medium for cholegraphy, calcium salt was precipitated in the tubules of rats and a gallstone containing contrast medium developed in a dog. A review is given of biotransformation of contrast media in the biliary and urinary tracts.

ZUSAMMENFASSUNG

Im Anschluss an die intravenöse Injektion eines Kontrastmittels zur Cholegraphie fielen Kalziumsalze in den Tubuli von Ratten aus und bei einem Hund entwickelte sich ein Gallenstein, der Kontrastmittel enthielt. Eine Übersicht über die Biotransformation von Kontrastmitteln in den Gallen- und Harnwegen wird gegeben.

RESUMÉ

Après injection intraveineuse d'un moyen de contraste pour cholangiographie, un sel de calcium a été precipité dans les tubules renaux de rats et un calcul biliaire contenant du moyen de contraste est apparu chez un chien. L'auteur fait une revue de la transformation biologique des moyens de contraste dans les voies biliaires et urinaires.

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ABNORMAL DUODENAL LOOP AND PYLORIC REGURGITATION

P THOMMESEN

Pyloric regurgitation and its possible significance as an etiologic factor in gastric ulcer has aroused increasing interest in the past few years (FLINT & GRECH 1970 BLACK et coll 1971 READ & GRECH 1973 WICKBORN et coll 1974) It was therefore considered of value to investigate whether duodenal anomalies and posture have any influence on pyloric regurgitation and whether a parasympathic drug (metochlopramide) has any effect on the regurgitation

An abnormal shape of the duodenal loop may be acquired or represent an anomaly but it is not always possible to differentiate between these conditions at radiography

Insufficient rotation of the duodenum around its longitudinal axis combined with disturbed rotation of the duodenum in relation to the long axis of the body cause the anomalies (SLAVENSKY 1969 LAUGE HANSEN 1973) The developmental disturbances may occur in more than one part of the duodenum resulting in a shape diverging from the normal one Abnormal segments are located anterior to or nearer the centre of the loop than normally A torsion groove develops at the junction of the abnormal segments and the duodenum may be fixed to the surrounding tissue by abnormal peritoneal folds

The torsion anomalies may be classified into three categories Proximal in the superior and descending parts of the duodenum distal where the horizontal part is abnormal and combined in which both the proximal and distal parts are involved

Submitted for publication – September 1976

SUMMARY

Following intravenous injection of a medium for cholegraphy calcium salt was precipitated in the tubules of rats and a gallstone containing contrast medium developed in a dog A review is given of biotransformation of contrast media in the biliary and urinary tracts

ZUSAMMENFASSUNG

Im Anschluss an die intravenose Injektion eines Kontrastmittels zur Cholegraphie fielen Kalziumsalze in den Tubuli von Ratten aus und bei einem Hund entwickelte sich ein Gallenstein der Kontrastmittel enthielt Eine Übersicht uber die Biotransformation von Kontrastmitteln in den Gallen und Harnwegen wird gegeben

RESUME

Apres injection intraveineuse d un moyen de contraste pour cholangiographie un sel de calcium a ete precipite dans les tubules renaux de rats et un calcul biliaire contenant du moyen de contraste est apparu chez un chien L auteur fait une revue de la transformation biologique des moyens de contraste dans les voies biliaires et urinaires

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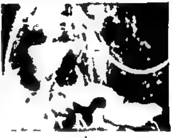


Fig 4 a) Immediate regurgitation following injection of 20 ml Mixobar into the duodenum with the patient supine b) Four min later The stomach is empty c) Immediate regurgitation following injection of 20 ml Mixobar with the patient erect d) Four min later Still contrast medium in the stomach

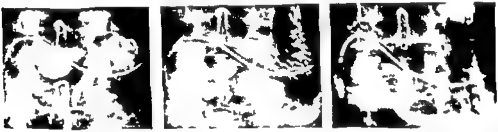


Fig 5 a) After placebo (1 ml 0 9 NaCl intravenously) No immediate regurgitation following duodenal injection of 20 ml Mixobar b) Four min later Contrast medium with fluid level in the stomach c) Four min following intravenous injection of 20 ml metochlopramide Immediate regurgitation following injection of 20 ml Mixobar d) Four min later Only slight mucosal coating of the stomach

These anomalies are characterized at radiologic examinations by a delay in the passage of the contrast medium the peristalsis is augmented and the segment oral to the torsion groove is often dilated (SLAVENSKY) Other anomalies are the short duodenum caused by reduced longitudinal growth of the descending and horizontal parts otherwise the duodenum has a normal shape and peritoneal fixation The area encircled by the duodenal loop is smaller than normally and not larger than the size of one lumbar vertebra

Fig 6 a) No nausea provoked by inserting the tube Immediate pyloric regurgitation to the stomach b) One month later nausea followed insertion of the tube Almost complete pyloric competence c) Five min later when nausea had disappeared massive pyloric regurgitation

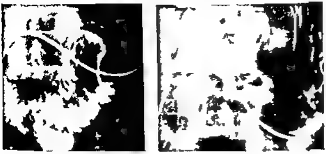
Material and Method

From the files 48 patients with varying degrees of upper abdominal dyspepsia but without ulcer at radiography were selected Eleven patients with a duodenal loop of normal appearance constituted group 1 and 14 patients with a proximal duodenal anomaly and passage hindrance high in the duodenum group 2 23 patients with a distal anomaly (14) or a short duodenal loop or combined anomaly (9) constituted group 3 The latter anomalies were classified in one group because it is sometimes difficult to distinguish the specific variants of these anomalies at radiography (SLAVENSKY) and also because the passage hindrance in these anomalies is mainly located in the distal part of the duodenum

Of the 48 patients 26 were males and 22 females the majority between 20 and 60 years of age The significance of the shape of the duodenum on pyloric regurgitation was analysed in all the patients the effect of posture in a total of 17 patients from groups 2 and 3 and the effect of metochlopramide in 12 patients with distal anomalies (group 3)

All subjects were fully aware of the nature and aim of the investigation to which they came fasting and had not used any drug for the past 24 hours Smoking was not allowed in the last six hours before the examination but on direct questioning 16 patients admitted that they had smoked 1 to 6 hours before After local pharyngeal anaesthesia a soft rubber tube was inserted under fluoroscopy through the nostrils into the descending part of the duodenum the tip of the tube being placed distal to the passage hindrance in group 2 and proximal to the hindrance in group 3 The position of the catheter was documented on a film Twenty ml Mixobar (22 C) was then instilled through the tube Fluoroscopy and exposure of the films were carried out immediately and after 4 minutes Pyloric regurgitation was considered to be present if enough contrast medium appeared in the stomach to form a fluid level at 4 min mucosal coating alone was not accepted as a sign of regurgitation

In the 17 patients in whom the effect of posture on pyloric regurgitation was also



a b

Fig 7 a) No pyloric regurgitation following injection of 20 ml Mixobar The bolus is propelled rapidly into the jejunum b) Towards end of investigation severe nausea and regurgitation suddenly occurred with mucosal coating of the entire stomach

recorded the procedure started with the supine position followed by the erect one each patient serving as his own control

Also in the analysis of the effect of metochlopramide each patient was his own control Placebo (1 ml 0 9 % NaCl) was given intravenously and the effect on pyloric regurgitation was recorded 4 min later in the same manner as mentioned In case of regurgitation the patient was placed supine in the right oblique position for about ten min by this time complete gastric emptying had occurred in almost every case The patient then received 20 mg metochlopramide intravenously After 4 min a film was exposed immediately before 20 ml Mixobar (22 C) was instilled into the duodenal loop Regurgitation was evaluated immediately and after 4 min The result was analysed by the chi square method with the use of Yates correction The level of significance was set at 5 per cent

Results

Pyloric regurgitation occurred significantly more often in patients belonging to group 3 (19 of 23 patients $\chi^2 = 12\ 4$ 3 84 at 5 % level) than in group 1 (2 of 11) (Figs 1 2) No evident difference could be demonstrated between group 1 and patients with proximal duodenal anomalies (group 2) (5 of 14 patients $\chi = 1\ 20$ 3 84 at 5 % level) (Fig 3)

Regurgitation occurred in 11 of 17 patients in erect position but in none of these when supine The supine position thus seemed to prevent pyloric regurgitation (χ 16 3) (Fig 4) in those cases in which regurgitation in the supine and erect positions was compared Regurgitation in the erect position was more effectively prevented by metochlopramide than by placebo (7/12 and 2/12 respectively $\chi = 4\ 61$ 3 84 at 5 % level) (Fig 5)

Discussion

The results suggest that a relation exists between pyloric regurgitation the shape of the duodenal loop and the position of the patient and that metochlopramide has an effect on the regurgitation Although it is shown that a tube through the pyloric channel does not significantly affect the regurgitation (READ & GRECH) several

THE DOUBLE CONTRAST EXAMINATION OF THE COLON Experiences with the Welin modification By Solve Welin and Grethe Welin 120 pages with 86 figures and 5 tables Price DM 90 Georg Thieme Verlag Stuttgart 1975

The authors have reviewed the experiences gained from over 50 000 investigations of the colon using the double contrast technique Gradual improvements have been made in the technique over the years and it is described in detail Various methods for irrigating the colon are thoroughly treated and polyp diagnosis in which the Malmo school is a leader is also dealt with exhaustively This section like all the others includes not only the roentgen diagnosis but also a comprehensive description of the pathology and the clinical aspects On the other hand there is no mention of colonoscopy and of the new aspects which this method has presented for the diagnosis and treatment of colon polyps

The chapter on diverticula contains a full account of their pathology and of different theories regarding their mode of origin The value of the double contrast technique in the diagnosis of diverticular conditions is also stressed However if acute inflammation is present the examination cannot always be performed because of the pain reaction

Bleeding from a colon diverticulum can according to these authors be diagnosed only by excluding all other conceivable haemorrhagic sources The possibility of demonstrating the source of the bleeding by selective angiography in the case of severe haemorrhage or by colonoscopy when the bleeding is moderate is not mentioned

The chapters on colitis are comprehensive and include the description of a valuable sign of Crohn s disease not previously given much attention namely transverse contrast stripes which do not occur in ulcerative colitis In the early stages of the latter disease diagnosed by endoscopy the intestine is interpreted as normal in about 15 per cent of the cases with the conventional technique When the double contrast technique is used this discrepancy is said to be eliminated According to other authors however even when the appearances are normal at an examination using the double contrast technique a superficial colitis may be established with a colonoscopy The difficulty of demonstrating malignancy in colitis even when a sensitive double contrast technique is used is stressed

The book contains many illustrations all of excellent quality and it admirably demonstrates the great value of the double contrast technique for examination of the colon It should be read by all radiologists and gastroenterologists

Nils Gabrielsson

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR KNUT DALE) OSLO SANITETS FORENINGS REVMATISMESYKEHUS OSLO NORWAY

RADIOGRAPHIC EVALUATION OF RHEUMATOID ARTHRITIS AND RELATED CONDITIONS BY STANDARD REFERENCE FILMS

ARVI LARSEN KNUT DALE and MORTEN EEK

Radiography is of primary importance in the evaluation of chronic inflammatory conditions with joint manifestations such as rheumatoid arthritis ankylosing spondylitis and psoriatic arthropathy As yet no system has been presented having proven reproducibility and validity for grading the severity of arthritis in these conditions The absence of a satisfactory evaluation system has been obvious especially in therapeutic and epidemiologic investigations on rheumatoid arthritis In this report a short review on the radiographic evaluation of arthritis is given and a new system based on standard reference films is introduced

Previous systems for evaluation of arthritis

The first attempt towards a standardized evaluation of rheumatoid arthritis dates back to 1949 when through the initiative of the American Rheumatism Association, four stages were introduced (STEINBROCKER et coll 1949) still the most commonly used grading The radiographic criteria of the four stages are as follows Stage I Osteoporosis may exist no erosions Stage II Osteoporosis slight cartilage or subchondral bone destruction may be present Stage III Osteoporosis cartilage and bone destruction Stage IV Same as III with bony ankylosis

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Several difficulties are involved when applying this system The evaluation may be based on any single joint without the grading providing information about the other joints *An osteoporotic joint may be* graded either as first or second stage The difference between the second and third stages is vague Bony ankylosis as a criterion of the most severe stage is not acceptable in actual fact the new bone formation leading to ankylosis is a reparative process in arthritis (GARDNER 1965)

The Atlas of standard radiographs of arthritis which represented a remarkable methodologic advance was published in 1962 mainly for epidemiologic investigations of arthritis (KELLGREN et coll 1963) This atlas contains paper prints of standard reference films for the hand with the wrist the forefoot and the cervical spine illustrating the second to fourth stages of rheumatoid arthritis the zero and first stage remaining verbally described The atlas presented a new idea in definition reference to figures instead of words However the illustrations are small implying that it is difficult to observe the erosive and joint space abnormalities characterizing the different stages

The two systems mentioned are designed to classify patients with rheumatoid arthritis according to the grade of the lesion in one or a few joints Therapeutic trials in arthritis need more accurate evaluation a good example being the scoring system used in the Empire Rheumatism Council investigation of gold therapy in 1961 In this system 20 finger joints in the final films were compared with those in the initial films The new erosions extensions of old erosions and narrowed joint spaces were scored A more detailed scoring system for erosions and joint space narrowing in the hands and wrists was presented by SHARP et coll (1971)

Development of the present system

The first version of the present system was developed at the Rheumatism Foundation Hospital Heinola Finland (LARSEN 1974) Films demonstrating 6 stages were produced with Logetronics equipment and the joints illustrated in life size on one sheet of film The first stage represented the normal condition and the subsequent ones a gradual progressive deterioration the criteria being bone destruction and cartilage reduction based on conclusions reached in reviewing the pathology and radiology of rheumatoid arthritis An interobserver analysis with these standard films demonstrated that 9 out of 10 arthritis films may be staged uniformly by 6 observers A parallel result was obtained using the system in a radiologic quiz arranged during the XIII Scandinavian Congress of Rheumatology (LARSEN 1974)

The first independent testing of the system took place in this department of radiology (DALE & EEK 1975) An inability of the system to record slight abnormalities in arthritis was revealed which resulted in a modification of the system by referring to a normal joint as zero and to a joint with slight abnormalities as grade I This modified system was tested on 560 films of several types of arthritis in a variety of joints The agreement in the evaluation of seropositive and seronegative rheumatoid

Table 1

Agreement of two radiologists in reading films of different types of arthritis using standard films as comparison

	Seropositive rheumatoid arthritis		Seronegative rheumatoid arthritis		Psoriatic arthropathy		Ankylosing spondylitis		Total	
	No		No		No		No		No	
Patients	67		16		6		11		100	
Films with satisfactory agreement	362	89	58	81	36	95	30	67	486	87
Films with poor agreement	43	11	14	19	2	5	15	33	74	13
Total	405	100	72	100	38	100	45	100	560	100

arthritis ankylosing spondylitis and psoriatic arthropathy appears in Tables 1 and 2 The agreement was considered satisfactory if both observers graded the film within the same stage or two adjacent stages It was considered poor if the evaluation differed by more than two stages About 90 per cent agreement was obtained in seropositive rheumatoid arthritis and in psoriatic arthropathy whereas poor agreement was more usual in seronegative arthritis and in ankylosing spondylitis The poor agreement was attributed to the tendency to bony ankylosis or new bone forma

Table 2

Agreement of two radiologists in reading films of different types of arthritis using standard films as comparison Distribution of joints examined

Joints	Total No	Satisfactory	Poor			
			Seropositive rheumatoid arthritis	Seronegative rheumatoid arthritis	Psoriatic arthropathy	Ankylosing spondylitis
Wrist	124	103	16	4		1
MCP	102	96	3	2		1
PIP	82	73	3	2		4
DIP	8	5			1	
Shoulder	29	26	2			1
Elbow	35	33	1		1	
Hip	35	26	3	3		3
Knee	51	38	7	3		3
Ankle/tarsus	35	30	5			
MTP	44	39	3			2
IP	17	17				
Total	560	486	43	14	2	15

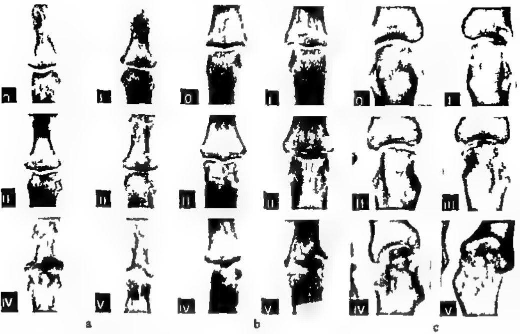

Fig 1 Standard films Stages in the finger joints a) Distal interphalangeal joint b) Proximal inter phalangeal joint c) Metacarpophalangeal joint

tion which made the evaluation of the films difficult It was concluded that the system may be used as a semiquantitative measure of several kinds of arthritis when bony ankylosis or predominant new bone formation are not present

Following this testing a revision of the first version was considered necessary This revision as presented below was made by the present authors in close collabora tion

Standard reference films for evaluation of arthritis

The present standard reference films for evaluation of arthritis demonstrate the radiographic criteria for the grading of the severity of the lesion Standard films of the finger joints appear in Fig 1 of the wrist in Fig 2 and of the hip in Fig 3 Films from patients for comparison with standard films are given in Figs 4 and 5

Conventional equipment and standard projections of the joints were used but only films of antero-posterior projection were chosen for standards except for the tarsus which was exposed in lateral projection The joints were exposed without weight bearing The right and left joints were exposed on the same film except for the tarsus and the shoulder The focus cassette distance was 100 cm Grids were used for the shoulder and hip joints and intensifying screens were used for all standard films The mean exposure values were for the wrist 42 kV 100 mA 1 6 s and for the hip 60 kV 100 mA 4 s The films were developed by an automated developer for 90 seconds

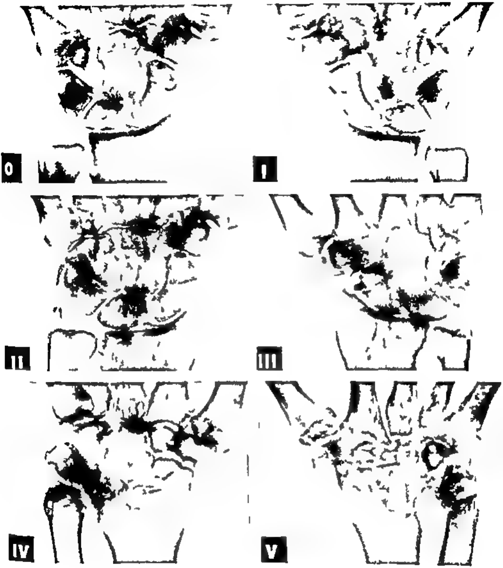

Fig. 2 Standard films Stages in the wrist

The individual films for the standard series were selected according to the following principles The films originated from adult women with rheumatoid arthritis and a positive or negative rheumatoid factor The films of the zero and the first stage represented symmetrical joints of the same patient or the same joint at different times to illustrate the delicate abnormalities of the first stage and to emphasize the value of comparing films of possibly pathologic joints with unaffected joints in a contra lateral or previous film The films demonstrating the outer stages originated from different patients The radiographic criteria of the separate stages are itemized later

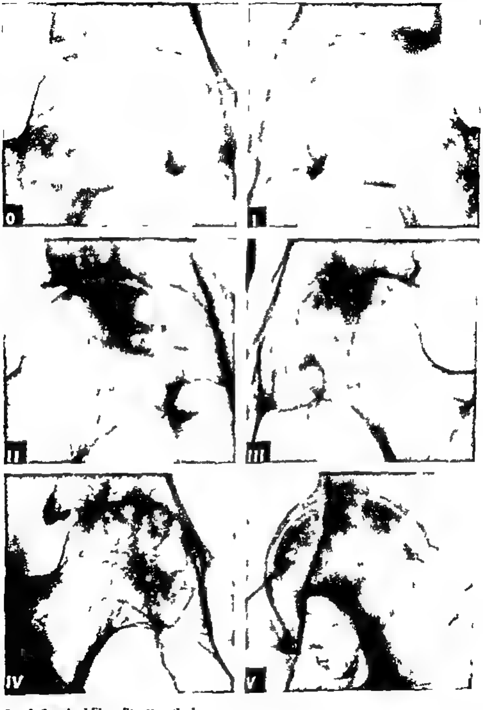

Fig. 3 Standard films Stages in the hip

Fig 4 Hands from a patient with rheumatoid arthritis Right wrist Previous synovectomy arthritis grade III Left wrist Grade IV (cf Fig 2)

The standard series demonstrating each joint at different stages were prepared as follows Films representing the different stages of one joint were glued with the legends on to a transparent plastic sheet The model sheets were duplicated on a radiographic duplicating film (Kodak RP/D X Omat 24 cm × 30 cm)

The following joints were included in the standard series The distal interphalangeal joint (DIP) of the finger the proximal interphalangeal joint (PIP) of the finger the metacarpophalangeal joint (MCP) the wrist the elbow the shoulder the hip the knee the ankle the tarsus the first metatarsophalangeal joint (MTP I) other metatarsophalangeal joints (MTP II–V) and the interphalangeal joint of the great toe (IP)

As a supplement to these illustrations the following descriptions of the stages should be considered when using the system

Grade 0 Normal conditions Abnormalities not related to arthritis such as marginal bone deposition may be present

Grade I Slight abnormality One or more of the following le ions are present periarticular soft tissue swelling periarticular osteoporosis and slight joint space narrowing When possible use for comparison a normal contralateral or a previous film of the joint in the same patient as demonstrated in the standard series The standard series illustrates a characteristic osteoporosis and joint space narrowing whereas no attempt was made to demonstrate the appearance of soft tissue Soft

Fig 5 Hips from a patient with ankylosing spondylitis The arthritis (grade III) in the right hip is easily graded (cf Fig 3) On the left side a bony bridge on the lateral rim of the acetabulum has hindered marked narrowing of the joint space the grading is uncertain

tissue swelling and osteoporosis may be reversible This stage represents an early uncertain phase of arthritis or a later phase without destruction Compatible appear ances may occur without arthritis in old age traumatic conditions Sudeck s atrophy etc

Grade II Definite early abnormality Erosion and joint space narrowing cor responding to the standards Erosion is obligatory except in the weight bearing joints

Grade III Medium destructive abnormality Erosion and joint space narrowing corresponding to the standards Erosion is obligatory in all joints

Grade IV Severe destructive abnormality Erosion and joint space narrowing corresponding to the standards Bone deformation is present in the weight bearing joints

Grade V Mutilating abnormality The original articular surfaces have disappeared Gross bone deformation is present in the weight bearing joints Dislocation and bony ankylosis being late and secondary should not be considered in the grading if present the grading should be made according to the concomitant bone destruction or deformation

There may sometimes especially in the erosive phase of arthritis be some disparity between the degree of erosion and the narrowing of the joint space, because loosening of joint ligaments and the presence of excess joint fluid may cause widening of the joint space If so the degree of erosion should be the decisive factor when using the present grading system

Discussion

The present system offers a possibility to reproduce radiographic evaluation of arthritis in the essential joints of the extremities The reproducibility has been tested

several times with the general result that different observers uniformly graded 90 per cent of films of rheumatoid arthritis (LARSEN 1973 1974 DALE & ECK) The validity of the radiographic criteria is based on the joint pathology

The present system is not specific for rheumatoid arthritis When new bone formation is not predominant it is possible to evaluate extremity joints in other chronic inflammatory conditions such as ankylosing spondylitis and psoriatic arthropathy which are known to present many common features in joint pathology (GARDNER) However the system is not suited for evaluating juvenile rheumatoid arthritis or arthropathies in childhood with abnormal epiphyseal development Osteoarthrosis may cause abnormalities comparable with grade I or even more severe grades particularly in the interphalangeal joints of the fingers (erosive osteoarthrosis) in the hips and in the knees Osteoarthrosis is usually differentiated by the presence of osteophytes and sclerosis but special difficulties may occur in osteoarthrosis secondary to arthritis The system should not be used for differential diagnosis without considering the clinical and laboratory data as well as the result of radiography of the spine and sacroiliac joints

In addition to the technique described for the present system special methods for soft tissue examination may be used to establish an early diagnosis of arthritis (SOILA 1957 FISCHER & BRAUN 1973 REICHMANN et coll 1974 1975 DEICHGRABER & OLSSON 1975) This matter will not be further discussed here because joint films of conventional techniques are used in the present system For this reason films of weight bearing positions in the lower extremity joints were not used This technique has proved valuable in detecting narrowing of the joint space in osteoarthrosis (AHLBACK 1968) where the cartilage reduction in the early stage is more localised contrary to the more often general reduction in an arthritic joint The intention was to examine the lower and the upper extremity joints by conventional technique under uniform conditions Moreover the weight bearing position is often painful for patients with arthritis If a standing position is preferred when examining the lower extremity joints the present grading system can be used The grading of the films of the supine or standing position seems to differ very seldom in arthritis and never more than one grade

The present system is a purely radiographic evaluation method for arthritis It should not be considered as a general measure of the severity of the disease Clinical and functional evaluation are of equal importance for the total evaluation of joints

In the statistical data processing it should be considered that the grading in the present system follows ordinal scale Hence the statistical methods should be operable in this scale

In rheumatology it is customary to use such concepts as the stage of arthritis in an individual patient Such a generalization may in many cases be arbitrary and even misleading The human body has about 190 synovial joints and several extraarticular manifestations occur in rheumatoid arthritis and other inflammatory joint lesions The joints and other features should be evaluated separately It should be emphasized

that individual joints in one patient may present different stages in the present system The individual joints are in this system dissociated from a common time table Progress of arthritis may be found in some joints while other joints are un changed Thus if the present system is used for classifying the patients the joint selection and the stages of these joints should be reported individually

The present system is recommended for the following purposes

1 In diagnostic radiology for numerical evaluation of arthritis and for recording of spontaneous variations of the disease
2 In therapeutic connections for evaluating disease progression The system is applicable both in trials of drugs and in synovectomy
3 In epidemiology of arthritis for exact recording of lesions in individual joints

Duplicates and copies of the standard films are available on request

SUMMARY

A review of radiographic evaluation of rheumatoid arthritis is given Standard reference films are introduced for evaluation of rheumatoid arthritis and related conditions in the extremity joints In this system numerical evaluation of arthritis is given for individual joints in a patient

ZUSAMMENFASSUNG

Eine Übersicht uber die rontgenologische Auswertung der rheumatoiden Arthritis wird gegeben Standardreferenzfilme zur Auswertung der rheumatoiden Arthritis und ahnlichen Bedingungen der Extremitatengelenke werden eingefuhrt Bei diesem System wird eine numerische Auswertung einer Arthritis fur die individuellen Gelenke eines Patienten gegeben

RÉSUMÉ

Les auteurs présentent une méthode d évaluation radiographique de l arthrite rhumatismale Ils utilisent des radiographies standard de référence pour évaluer les lésions de l arthrite rhumatismale et les affections apparentées sur les articulations des membres Dans ce système on établit une évaluation numérique de l arthrite pour chaque articulation d un malade

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CORTICAL INDEX OF THE FEMORAL NECK

N FREDENSBORG and B E NILSSON

Evaluation of the cortical thickness in diaphyseal bone on roentgen films has been demonstrated to be a useful tool for the estimation of bone mass in man The mid shaft of the femur (GARN et coll 1964) the metacarpal bones (BARNETT & NORDIN 1960) or the proximal end of the radius (MEEMA 1963) are usually chosen These sites are well suited as the cortex is well defined and standard projections are easily obtained routine films taken for other purposes may be used However none of these sites is of particular interest with regard to fragility fractures as shaft fractures of long bones are not typical of bone fragility (BUHR & COOKE 1959) On the other hand one pertinent cortical structure is the cortex of the femoral neck which is directly involved in fractures of the upper end of the femur

The intention of the present investigation was to determine the cortical thickness of the femoral neck in normal subjects and in women with fracture of the upper end of the femur

Material and Method

For the purpose of age and sex comparison within the reference group of altogether 120 patients 10 males and 10 females were sampled in each 10-year age group between 20 and 80 In each case a pelvic film had been exposed including both hip joints and the upper end of the femur at least to the level of the lesser trochanter The projection was standard a p centered in the mid pelvis the hips rotated slightly inward The film focus distance was 125 cm

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Fig 1

Fig 2

Fig. 1 Suitable measuring sites as indicated on the film

Fig 2. The projected shape of the medial cortex is slightly triangular and the inner edge is poorly defined The film is a border line case of what may be accepted for measurements

Thirty women with femoral neck fracture and 30 women with trochanteric fracture were selected at random Patients with possible degenerative joint disease (osteoarthrosis) or other local lesions were excluded The fracture cases were evenly distributed between 60 and 80 years of age

In addition 60 apparently normal hips were selected of the same age as the fracture cases and measured in the same way

Both sets of normal cases constituted individuals who had been referred for radiography because of trauma as a complement to a spine examination or in conjunction with a skeletal survey which had displayed no abnormality Thus there was no evidence of pathology in these films

Cortical thickness was measured immediately proximal to the lesser trochanter (Fig 1) The measure of the thickness of the medial cortex was divided with the width of the femoral neck in its most narrow part The ratio is referred to as the cortical index of the femoral neck It was usually possible to find a region with an even cortical thickness in which the measurements could be made patients were excluded if this was not possible In some cases the border line between the marrow cavity and the cortex was poorly defined (Fig 2) Difficulties in obtaining good measurements were not related to the age of the patient Outward rotation of the hip prevented accurate measurement Rejection of films for measurement was as frequent in fracture cases as in controls In the controls both hips were measured in the fracture cases only the contra lateral uninjured hip The cortex was measured repeatedly with a difference of less than 1 0 mm between the measurements

Results

There was no systematic left–right difference Therefore in the normal cases with both hips measured the average of the values of the two hips was used The

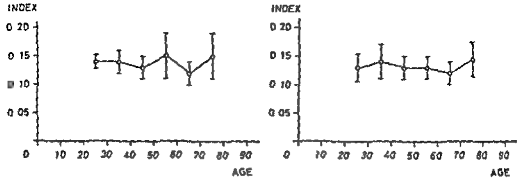

Fig 3 Cortical index of the femoral neck Relation to age and sex (males to the left and females to the right)

age and sex distribution of the femoral neck index in the reference group of 120 cases appears in Fig 3 The index did not significantly decrease with age Instead a tendency was found towards an increase in the oldest age groups in men as well as in women

The values of the cortical index in fracture cases as compared to the control series are given in the Table A significant difference existed between each of the two fracture groups and the controls ($p < 0\ 001$) In the comparison between trochanteric and neck fractures the cortical index of the femoral neck in the latter group appears to be somewhat less but the difference is not quite significant ($0\ 1 < p < 0\ 05$) An almost perfect normal distribution of the index values in control and fracture cases was found fracture cases occupying the lower and control cases the upper part of the distribution (Fig 4)

Discussion

VOSE & LOCKWOOD (1965) demonstrated decreased bone mineral content in the femoral neck in cases of femoral neck fracture Also the epidemiology of neck fracture indicates that this is an injury mainly caused by a decreasing quality of the skeleton (ALFFRAM 1964) In the present material measurements concerned a variable of bone mass which does not follow the usual decline with age Nevertheless this

Table

Cortical index of the femoral neck

	No of cases	Mean	SD
Controls	60	0 136	0 026
Neck fractures	30	0 094	0 019
Trochanteric fractures	30	0 104	0 024

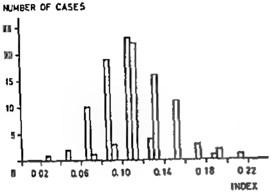

Fig. 4. Cortical index of the femoral neck in control and fracture (female) groups. ☐ controls ☐ fractures

variable is significantly decreased in individuals with fracture of the upper end of the femur. There are two possible explanations: either these patients have lost considerably more bone from their femoral neck than the average, or the cortex of the femoral neck was primarily thinner. A combination of the two is also possible.

The cortex of the femoral neck is probably not a useful variable for morphometric evaluation of bone mass. However, it may have some use as an instrument to predict femoral neck fracture.

SUMMARY

The thickness of the medial cortex of the femoral neck does not decrease with age in the same way as other common parameters of bone mass. However, in women with fracture of the upper end of the femur it is below normal. The variable, expressed as the cortical index of the femoral neck, may have some use in predicting the risk of femoral neck fracture from routine films of the hip.

ZUSAMMENFASSUNG

Die Dicke der medialen Cortex des Femurhalses nimmt nicht mit dem Alter in der gleichen Weise wie andere gewöhnliche Parameter der Knochenmasse ab. Bei Frauen mit Frakturen des oberen Endes des Femur ist diese jedoch geringer als normal. Diese Variable, ausgedrückt als der corticale Index des Femurhalses, mag eine Vorhersage des Risikos einer Femurhalsfraktur von Routinefilmen der Hüfte ermöglichen.

RESUMÉ

L'épaisseur de la corticale interne du col du fémur ne diminue pas avec l'âge de la même façon que les autres paramètres habituels de la masse osseuse. Cependant, chez les femmes ayant une fracture de l'extrémité supérieure du fémur, elle est au dessous de la normale. Cette variable, exprimée comme l'index cortical du col fémoral, peut avoir un intérêt pour prévoir le risque de fracture du col du fémur d'après des radiographies simples de la hanche.

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GASTROCNEMIO SEMIMEMBRANOSUS BURSA AND ITS RELATION TO THE KNEE JOINT

I Anatomy and histology

P G LINDGREN and R WILLEN

A swelling in the popliteal region was first described in 1840 by ADAMS who considered it to be due to enlargement of the bursa lying beneath the medial head of the gastrocnemius muscle He also reported that the bursa communicated with the knee joint by a species of valvular opening without describing the details further ADAMS concluded that the condition resulted from arthritis

The anatomy of enlarged bursae and of their communication with the knee joint was described by GRUBER (1845 1869 1885) He stated that the opening between the joint and the gastrocnemio-semimembranosus bursa consisted of either one or several small round holes

FOUCHER (1856) presented 11 autopsy cases and 19 patients with popliteal cysts He favoured the hypothesis that cysts at this site generally consisted in distended bursae especially the bursa lying beneath the medial head of the gastrocnemius muscle

BAKER (1877 1885) described 8 cases of swelling in the popliteal region He considered that this condition might be due to herniation of the synovial membrane of the knee joint forming a cyst caused in turn by hydrops resulting from osteoarthritis Such popliteal cysts have since then been called Baker s cysts

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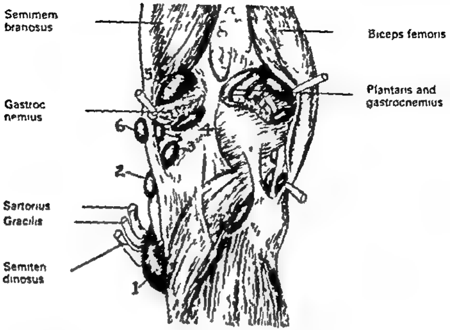


Fig. 1 Six bursae described by WILSON et coll Bursae 4 and 5 usually communicate with one another and are therefore described as one bursa and called the gastrocnemio-semimenbranosus bursa (Modified from CALLANDER)

BAKER also expressed the opinion that distension of a normally occurring bursa could be an underlying mechanism Several authors have described sporadic cases of popliteal swelling (e g CRAVENER 1932 SNODGRASS 1936 HAGGART 1938 1943) HAGGART considered that in most cases it was due to herniation of the synovial membrane caused by sudden hyperextension of the knee joint and only exceptionally to distension of a bursa

WILSON et coll (1938) on the basis of the literature and of their own dissections of 30 autopsy cases made a summarizing presentation of the postero-medial bursae (Fig. 1)

Bursa No 4 in the figure between the medial head of the gastrocnemius and the capsule over the medial condyle of the femur and bursa No 5 between the superficial surface of the medial head of the gastrocnemius and the overlying semimembranosus muscle were described as one single bursa and called the gastrocnemio-semimembranosus bursa

WILSON et coll also made microscopic examinations of material from their dissections and conducted clinical investigations of 21 patients but made no direct histologic comparison between material from the joint capsule and the bursa nor did they compare different age groups They were of the opinion that there was strong evidence that a cystic swelling at the back of the knee was due to an expansion of the gastrocnemio-semimembranosus bursa and not to herniation of the synovial mem

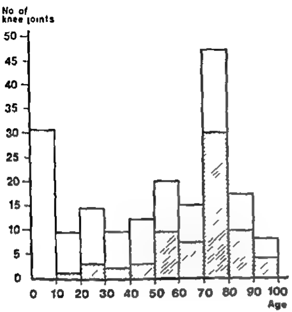


Fig 2 Radiologic findings in 182 knee joints Frequency of gastrocnemio-semimembranosus bursa communicating with the knee joint (shaded areas) and without communication (non shaded areas) 10-year-old patients are included in the 10 to 20 decade, 20-year-olds in the 20 to 30 decade etc

brane Several authors have since discussed this aetiologic problem (KUHN & HEMPHILL 1944 CHILDRESS 1954 BURLESON et coll 1956 GRISTINA & WILSON 1964 DOPPMAN 1965 FISCHEDICK 1969 PALLARDY et coll 1969 REINHARDT 1972 WOLFE & COLLOFF 1972 GREPL 1973)

The aim of the present investigation was to attempt to clarify whether a cystic formation in the medial popliteal region is due to herniation of the synovial membrane or to distension of a normally occurring gastrocnemio-semimembranosus bursa

Material Radiography was performed of 182 knee joints in 100 autopsy cases The age distribution is given in Fig 2 In 80 knee joints this examination was followed by dissection and specimens were taken for histologic examination The autopsy cases were selected randomly but an attempt was made to include as many age categories as possible No patients in the material had a known joint disease

Methods

Radiography In adults 20 ml of contrast medium (Urografin 45 %) were injected into the knee joint in the same way as in clinical arthrography In children the amount of contrast medium varied according to the size of the child After the injection the knee was flexed and extended 5 to 6 times to allow filling of the gastrocnemio-semimembranosus bursa On flexion of the knee joint the pressure in the suprapatellar recess increases and any fluid in the joint will then fill the posterior recesses and the

a b c

Fig 3 a) Contrast medium injected into a gastrocnemio semimembranosus bursa not communicating with the knee joint b) Same case Injection also into the knee joint c) A gastrocnemio-semimembranosus bursa communicating with the knee joint Injection into the joint The bursa is similar in appearance to that in (a) and (b) S = impression by semimembranosus muscle G = impression by gastrocnemius muscle

Results

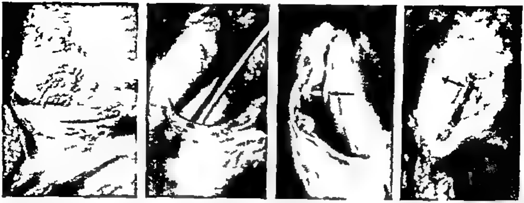
Radiography

No discrepancies were found between the roentgenologic observations and the findings in the 80 knee joints Thus at the dissections no communication between the joint and the bursa was found which had not been demonstrated at radiography

In 5 of the 9 knee joints in which contrast medium was injected directly into the bursa from the posterior aspect no communication with the joint was present The appearance of these bursae was radiographically similar to that of the bursae which had been filled from the knee joint through an opening between the joint and the bursa (Fig 3) The impressions in the bursa are due to the gastrocnemius and semimembranosus muscles (LINDGREN 1977 a) Communications between the joint and the bursa were found in greater frequencies in older age groups (Fig 2) Thus no opening was found in any child below 10 years of age whereas one was present in more than half of the adults over 50 years old

Dissections

The gastrocnemio semimembranosus bursa was present in all cases and was located between the tendons of the gastrocnemius and semimembranosus muscles part of it lay anterior to the tendon of the medial head of the gastrocnemius Anteriorly the bursa was delimited by the posterior surface of the capsule and the upper part of its wall bordering against the joint was thinner than its other parts the thinnest part being at the proximal point where the tendon of the medial head of the gastrocnemius



a b c d

Fig 4 a) Medio-posterior part of the joint capsule seen from the knee joint Slit opening into the gastrocnemio-semimembranosus bursa b) Probe in the slit *The upper margin of the slit is sharply* defined and thin c) The slit viewed from above Remnants (→) of thin membranous tissue in the lower part d) The bursa viewed from behind Probe (↔) in the bursa demonstrating the thin posterior wall

left the joint capsule In 68 of 182 cases a communication was found between the joint and the bursa (Fig 2) This almost invariably took the form of a transverse slit (Fig 4 a–c) In the middle and upper parts of the slit the anterior wall was thin and the edge of the opening was sharply defined The opening was always located posterior to the medial femoral condyle at the site where the tendon of the medial head of the gastrocnemius left the joint capsule The width of the slit generally varied between 15 and 20 mm but in a few cases it was narrower—in one case as narrow as 6 mm

In 35 of 51 dissected specimens a fibrous membrane was found in the middle or lower part of the opening (Figs 4 c 5 6 b c) In 4 cases this membrane was thick and completely bridged the opening (Fig 5) In the other 31 cases the membrane only partially bridged the opening and varied in thickness Similar membranes in the anterior space of the bursa were observed in the same frequency in specimens from cases with no opening between the joint and bursa

The anterior wall of the bursa was thicker in children than in adults (Fig 6)

The parts of the wall of the bursa lying adjacent to the gastrocnemius and semimembranosus muscles adhered firmly to the fasciae The distal and upper parts of the posterior wall of the bursa were not adherent to any muscle and were very thin and macroscopically transparent (Fig 4 d)

In attempts at traction of the joint capsule in a proximal-distal direction a slit appeared at the site where the tendon of the medial head of the gastrocnemius left the capsule This was similar to the slits described Its upper margin was somewhat frayed however and a corresponding irregularity was observed in the posterior part of the joint capsule

When increasing amounts of contrast medium were injected into the joint a rupture occurred in the suprapatellar recess in 10 cases and in the postero-medial recess in one case In one further case a rupture occurred resulting in a communication with

Fig 5 Sagittal section through the joint capsule and a bursa Membranous septum (→) totally bridging the opening J = knee joint B = bursa S = slit

the bursa The width of this opening was 5 to 6 mm compared with a normal width of 15 to 20 mm It was located at the same place as the slits described At the site of the opening the posterior part of the capsule was very thin if the strain in that area had been greater the slit could easily have widened medio-laterally

Light microscopy

0–4 years (6 preparations) The joint capsule was composed of 3 to 5 layers of intermingled cuboid and elongated synovial cells The cuboid cells only partly covered the surface The layer of synovial cells which was rather thin formed a nodular outline Beneath this layer there were several large blood vessels and some loose connective tissue under which thick strands of connective tissue ran transversely vertically and even obliquely The transverse fibres were particularly coarse The upper posterior part of the capsule was attached to the tendon of the gastrocnemius

The gastrocnemio-semimembranosus bursa was similarly coated with both elongated and cuboid cells Up to 5 layers of cells intermingled with collagen connective tissue were observed Part of the anterior wall of the bursa was attached to strong underlying bundles of connective tissue interlaced with medium sized blood vessels and tendonous tissue The surface had a nodular outline The nearest distance between the joint capsule and the bursa was 3 to 5 mm (Fig 6 a) No degeneration or any inflammatory reaction was found Thus the surface layers of the capsule and the bursa had similar histologic appearances

5–15 years (6 preparations) The joint capsule had become coarser and contained distinct strands of fascia In the area between the tendon of the gastrocnemius and

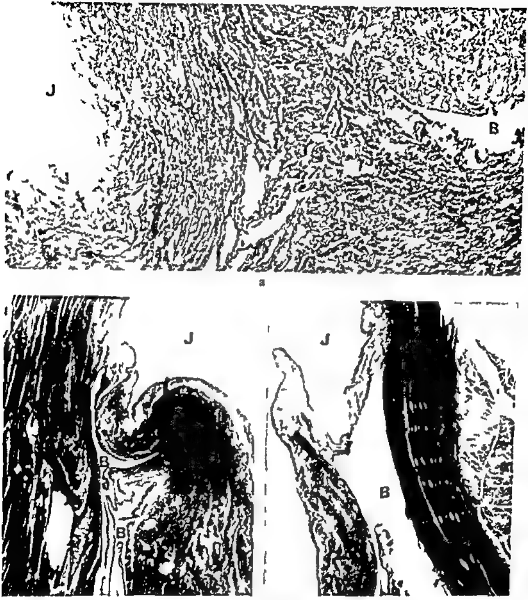


Fig 8 a) 3-day-old child Strong fibroelastic tissue between the joint and the bursa b) 8 year-old child The synovial membrane is thinner than in the patient in (a) Membranous septum (→) c) 65 year-old adult Slit with a thin membrane J = knee joint B = bursa Verhoeff–van Gieson 10

the transverse fibres of the capsular tissue often a loosely woven and slightly oedema tous zone (Fig 7) was present extending distally towards the tissue of the bursa

The bursa sometimes contained fibrin like material and in 2 cases thin s pta with spaces in between In one case the joint capsule had ruptured giving rise to an opening between the joint and bursa In this slit shaped opening a thin membranous

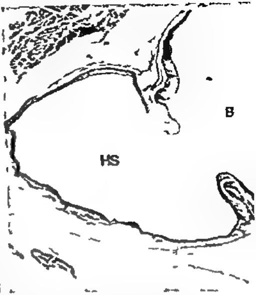


Fig. 7 8 year-old child Relatively large distance between the knee joint and the bursa with a loose oedematous zone (→) Verlhoeff-van Gieson ×40 b) 70-year-old adult. Herniation of part of the bursa into surrounding fatty tissue The communication between the bursa and the hernial sac has a softly rounded border Verlhoeff-van Gieson ×40 J = knee joint B – bursa HS hernial sac

tissue which had perforated was found In the remaining cases the distance between the capsule and bursa was 2 to 3 mm (Fig 6 b)

16–30 years (8 preparations) The joint capsule was composed mainly of elongated and sometimes more cuboid synovial cells but acellular areas were also found The capsular tissue was often smooth and slits were observed In 3 cases membranous septa were present between the capsule and bursa These membranes were degenerated with hyaline bodies and in some places calcific deposits

Degeneration with some acellular areas was also present in the wall of the bursa

30–50 years (10 preparations) In the joint capsule there was usually a marked paucity of cells In cases without a slit the tissue between the bursa and joint was thin and sometimes loose and oedematous The wall of the bursa was slightly thickened with up to 10 layers of cells and here also there was evidence of diffuse degeneration

50–90 years (13 preparations) In the joint capsule large areas of the synovial membrane were completely smooth with diffuse degeneration and a paucity of cells Occasional elongated synovial cells were present The collagen connective tissue in the capsule was often degenerated as also was the wall of the bursa which exhibited a sparsity of cells hyalinization and fibrinoid degeneration Degenerated membranes partially bridged the opening One bursa which communicated with the joint was greatly distended

In the distal parts of the bursa several sac like herniations into surrounding adipose tissue were observed (Fig 7 b) Their openings were fairly narrow with softly rounded margins

Scanning electron microscopy

Ten specimens of the joint capsule and bursa from autopsy cases with either a communication between these structures in both knee joints a communication in one knee joint only or no communication on either side were examined The ages of the patients varied between 30 and 72 years In all of these cases the findings in the tissue of the capsule and of the bursa were fairly similar regardless of whether any communication between the joint and the bursa was present or not

The surface of the capsule like that of the wall of the bursa had a wavy appearance and was coated with synovial cells some areas were smooth Zones with a honey combed structure where the synovial cells only partly covered the underlying bundles of collagen fibres were found in some cases These degenerative abnormalities were more marked in older individuals Fibrin occasional platelets and sometimes small remnants of contrast medium were also found on the surface

In cases with a communication between the joint and bursa more evident degeneration was observed the layer covering the collagen bundles being less complete both in the capsule and in the bursa (Figs 8 9)

Discussion

The frequency of communication between the gastrocnemio semimembranosus bursa and the knee joint was greater in the higher age groups (Fig 2) No discrepancy was found between the radiologic and anatomic findings That a slit might have occurred during the manipulations at the roentgen examination could have been a possible source of error However only in one case was any indication found that this might have happened In this case the upper margin of the slit was frayed and a corresponding irregularity was found in the posterior wall of the capsule The changes were similar to those produced when traction was applied experimentally to the joint capsule and resulted in a slit In all other cases the margin of the slit was sharp and no irregular counterpart in the posterior wall indicated that the opening had occurred post mortem

In 6 cases the slit contained a thin membranous septum (Fig 4 c) which had perforated Whether the perforation had taken place during the roentgen examination or before death could not be decided with certainty

These observations may only have marginally affected the results in Fig 2 and it is therefore considered that the results well reflect the frequencies of communication in vivo between a gastrocnemio-semimembranosus bursa and the knee joint

The causative mechanism underlying a popliteal or Baker s cyst has long been discussed and various theories have been presented (1) A herniation of the synovial

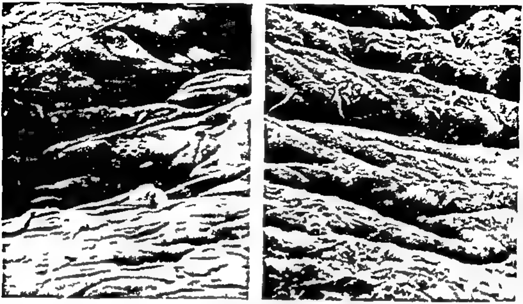
a

b

c

Fig 8 72 year-old adult Communication between the joint and the bursa in the right knee but not in the left Right knee a) Surface of joint capsule with soft ridges and degeneration The synovial cells have a honeycomb appearance and only partly cover the underlying collagen fibres 1 000 b) Same preparation Beneath the partly coating synovial cells are collagen fibres 3 000 c) Surface of the wall of the bursa with degeneration 1 000

membrane through a weak area in the posterior part of the joint capsule (2) rupture of the capsule posteriorly followed by efflux of fluid into the soft tissues resulting in a secondary reaction with formation of a membrane and encapsulation of fluid and (3) rupture of the capsule giving a communication with the normally occurring



a b

Fig 9 Same case as in Fig. 8 Left knee a) Surface of joint capsule Less marked degeneration and the synovial cells almost completely cover the surface 1 000 b) Surface of the wall of the bursa Degeneration only in few areas 1 000

gastrocnemio semimembranosus bursa In the presence of joint effusion fluid may enter the bursa which will expand and may rupture

The first two theories are improbable In the dissected material a cyst located separately from the normally occurring gastrocnemio-semimembranosus bursa was *never observed Neither has such a finding been reported in the literature*

No herniation of synovial membrane through a weak area of the capsule was evident in any of the cases Neither was any duplication of membranes or mural structures found indicating herniation of the synovial membrane into the normally occurring bursa Moreover the wall of the bursa and the wall of the joint capsule *had a similar microscopic appearance regardless of whether an opening was present* between the joint and the bursa or not (Figs 8 a b 9) Therefore the present results are in agreement with those of ADAMS among others that popliteal cysts occur by the third postulated mechanism

In the dissections it was noted that when an opening was present b tween the joint and the bursa this almost invariably had the same app arance slit shap d with a sharply defined cranially oriented margin (Fig 4 a–c) Further the op-ning was always located at the place where the tendon of th- gastrocnemius muscl- l ft the joint capsule In most cases the slit varied in width between 15 and 20 mm In cases with slits narrower than 15 mm the margin was thin and it was evident that further widening could have occurred

In the middle and lower parts of the opening m-mbranous septa of varying extent

and thickness were found It seems probable that in some cases these septa may hinder a flow of fluid and may constitute a valve mechanism between the joint and bursa (LINDGREN 1977 b) The gastrocnemio semimembranosus bursa was found in all dissected cases and in 9 of them contrast medium was injected directly into the bursa from the posterior aspect whereafter films were exposed in the conventional way *The appearance of this bursa was identical with that of the cavity which filled* with contrast medium after injection into the knee joint in cases where a communication was present (Fig 3)

At light microscopy the fibrous strands in the joint capsule caudal to the opening ran *transversely while those lying cranial to the opening ran vertically* the latter consisting mainly of tendonous material from the gastrocnemius With increasing age *this capsule became very thin* The capsular wall around the slit area consisted of thicker fibrous tissue Degeneration of the elongated synovial cells was observed even at early ages According to RHODIN (1974) the synovial surface consists of sparse fibroblasts with underlying reticular fibres thus mesenchymal tissue and not epithelial elements which also corresponds with the present observations

Scanning electron microscopy revealed that the surface layers of the joint capsule and the wall of the bursa were similar in structure regardless of whether the joint and bursa communicated or not The wavy contour of the capsular surface was better preserved in joints that did not communicate with the bursa than in those that did Correspondingly *general degeneration of the tissues was more marked in cases with* an opening between the joint and the bursa The degeneration in itself increases the *probability that such an opening will occur*

An interesting observation was that the synovial cells did not completely cover the underlying collagen bundles either in the joint capsule or in the wall of the bursa This was particulary evident in cases with marked degeneration and where the bursa and the joint communicated (Figs 8 9)

Various immediate causes of a communication between the knee joint and the gastrocnemio semimembranous bursa are possible in vivo

In young persons with a healthy joint capsule the opening is probably due to forceful extension or hyperextension of the knee joint The medio-posterior part of the capsule *is then stretched over the medial femoral condyle* which may cause a tear in the capsule

A slit of the same appearance and at the same location as *described could be* produced by experimental traction of the joint capsule in the cranio-caudal direction In these cases the upper margin of the slit was somewhat frayed and a corresponding irregularity was found in the posterior wall of the capsule

HAGGART (1938) noted that in several patients the symptoms followed hyperextension of the knee joint and considered that the popliteal swelling was due to herniation of the synovial membrane into the soft tissues posterior to the joint However it is possible *that the joint capsule became torn* allowing free passage of fluid from the joint to the gastrocnemio-semimembranosus bursa

An increasing tendency to hydrops due to arthrosis or other joint changes in older persons may be another factor contributing to a communication between the joint and the bursa On flexion of the knee the suprapatellar recess is compressed and if an increased amount of fluid is present in the joint this will be forced against the posterior recesses resulting in a pressure increase (CAUGHEY & BYWATERS 1963 LINDGREN 1977) When the knee is flexed the posterior part of the joint capsule is not stretched over the femoral condyle as in extension and the increase in pressure in the posterior part of the joint may lead to a rupture of a thin and degenerated capsule resulting in a communication with the gastrocnemio semimembranosus bursa Such a rupture occurred in the trials in which increasing amounts of contrast medium were injected into the knee joint and the joint was then flexed If the capsule was already torn but thin bridging membranes were present in the middle and lower parts of the slit (Figs 4 c 5) these membranes may rupture if the pressure increases in this way On the other hand when the knee joint is extended the pressure in the posterior part of the joint is lower and at the same time the joint capsule is protected against an increase in pressure by being compressed between the femoral condyle and the tendon of the medial head of the gastrocnemius muscle

Thus two different mechanisms are conceivable for the occurrence of an opening between the joint and the bursa—one on extension and the other on flexion of the knee joint Both mechanisms occur more easily with increasing age due to degeneration and reduced elasticity of the capsule When such an opening has occurred in the presence of joint effusion the bursa may expand especially posterior downwards and posterior upwards where its wall is very thin (Fig 4 d) and not adherent to any muscular tissue

Conclusions

A communication between the knee joint and the gastrocnemio-semimembranosus bursa is more frequently found in older individuals

In cases with a communication between the joint and the bursa the opening was invariably of similar morphologic appearance It was slit shaped with a sharp cranially oriented margin and was located at the site where the tendon of the medial head of the gastrocnemius muscle leaves the joint capsule

Degeneration of the joint capsule increases and its elasticity diminishes with age These conditions facilitate tearing of the posterior part of the capsule on extension or hyperextension of the knee joint, when the capsule is stretched over the medial femoral condyle With increasing age less and less strain is required for such a tear to occur

Fluid in the knee joint the prerequisites of which increase with age may also play a role causing a considerable rise in pressure in the dorsal part of the joint on flexion A communication between the joint and the bursa may then result either from a tear in a degenerated joint capsule or through a rupture of thin membranes in a previously formed slit

A communication between the knee joint and the gastrocnemio-semimembranosus bursa is thus an acquired condition If fluid is present in the joint when such an opening occurs the bursa readily distends to give a cyst like formation a so called Baker s cyst

SUMMARY

The gastrocnemio semimembranosus bursa and its relation to the knee joint was investigated in an autopsy material Arthrography dissection and microscopy were performed The area between the joint and the bursa is described The frequency of communicating bursa is higher in older individuals and this is due to degeneration of the joint capsule

ZUSAMMENFASSUNG

Das Verhaltnis zwischen der Bursa gastrocnemii semimembranosi und dem Kniegelenk wurde an einem Sektionsmaterial untersucht Arthrographie Dissektion und mikroskopische Untersuchung wurden ausgefuhrt Das Gewebe zwischen dem Gelenk und der Bursa wird beschrieben Die Frequenz einer kommunizierenden Bursa ist bei Älteren hoher und beruht auf der Degeneration der Gelenkkapsel

RESUME

La bourse commune au jumeau interne et au demi membraneux et ses relations avec l articulation du genou ont ete etudiees sur un matériel d autopsie Les auteurs ont fait une arthrographie une dissection et une etude microscopique Ils decrivent la region comprise entre l articulation et la bourse La communication de la bourse avec l articulation est plus fréquente chez les individus ages et ceci est du a la degenérescence de la capsule articulaire

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SIMULTANEOUS ARTHROGRAPHY OF THE TALOCRURAL AND TALONAVICULAR JOINTS IN CHILDREN

III Measurements on normal feet

ÅKE HJELMSTEDT and BO SAHLSTEDT

Abnormalities of the individual small bones in foot deformities in children are difficult to demonstrate roentgenologically because of the incomplete ossification of the foot skeleton Valuable information on the anatomy of the talus may be obtained however by simultaneous arthrography of the talocrural and talonavicular joints (Part II HJELMSTEDT & SAHLSTEDT 1976)

The degree of bone deformation may only be assessed when the normal variations have been established Values for certain variables of the talus obtained by arthrography on autopsy material and paediatric patients are now reported

In determining these normal values it must be considered that certain variables alter with age i e with the size of the talus

Material

The autopsy material consisted of 32 feet that exhibited no deformity on direct inspection or on dissection Most of the preparations were obtained from infants in

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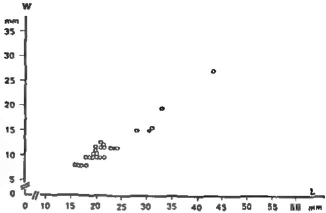

Fig 1 Linear correlation (r = 0 98) between length of talus (L) and width of talar trochlea (W) ○ autopsy material ● clinical material

the neonatal period (cf Part II) In the autopsy material the length of the talus varied between 16 0 and 43 0 mm with a mean value of 21 9 mm The width of the trochlea varied between 8 0 and 27 0 mm

The clinical material consisted of 22 normal feet in children with unilateral foot deformity The investigated foot exhibited no deformity at repeated clinical examinations over a period of several years The ages of the patients at the time of the arthrography varied between 2 months and 8 5 years The length of the talus varied between 23 5 and 57 0 mm with a mean value of 40 8 mm The width of the trochlea varied between 11 5 and 31 5 mm

The arthrographic technique and the projections used have been described previously (Part I SAHLSTEDT 1976) The accuracy of the method with respect to different measurable factors has also been reported previously (Part II) for the variables discussed in this report the reproducibility was found to be good

Variables The width of the trochlea (W) was measured on a p films of the ankle (Fig 1 b in Part I)

The length of the talus (L) was measured in the lateral view (Fig 3 b in Part I)

The radius of the trochlear curvature (R) was measured on lateral films of the ankle with the use of circular stencils For this measurement the curvature of the trochlea was approximated to the arc of a circle the chord (C) of which was measured as depicted in Fig 3 b in Part I The central angle (α) of the segment was measured with a protractor and was also calculated trigonometrically

The plantar deviation of the talonavicular joint was measured on lateral films and expressed as the angle (β) between the base line of the trochlea and the normal of the base line of the talonavicular joint (Fig 3 c Part I)

The medial deviation of the talonavicular joint was expressed as the angle (γ) between the normal of the base line of the talonavicular joint and the bisector of

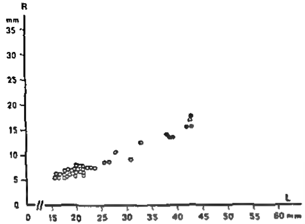

Fig. 2 Linear correlation ($r = 0.99$) between radius of trochlear curvature (R) and length of talus (L) Symbols as in Fig. 1

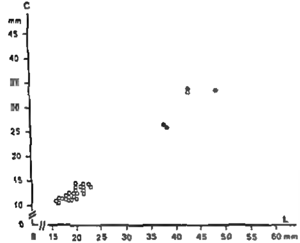

Fig 3 Linear correlation ($r = 0.99$) between chord of trochlear curvature (C) and length of talus (L) Symbols as in Fig. 1

the angle between the medial and lateral trochlear margins (Fig 4 b Part I) The measurements were made on dorso plantar films of the foot

Statistical methods The variations of the variables investigated are expressed as tolerance limits These limits contain with a certain confidence (γ) a certain proportion ($1-\alpha$) of a normally distributed population and may be calculated as $\bar{x} \pm k$ SD where $\bar{x}$ and SD are the mean and standard deviation respectively calculated from the data k is a constant depending on α γ and n (the number of observations) (OWEN 1962) Since this kind of limit is sensitive to departures from the normality assumption there is often a need for distribution—free tolerance limits This kind of limit was in fact tested on the present material but the results were about the same and it was therefore not applied

Table 1

Results of the roentgenologic measurements of the talar variables α_1 = the central angle of the trochlear curvature measured on the film and α_2 = the same angle calculated trigonometrically R = the radius of the trochlear curvature and C = the chord L = the length of the talus and W the width of the trochlea β = the plantar and γ = the medial deviation of the talonavicular joint

Variable	Autopsy material n 32		Clinical material n 22		Total material n 54	
	Mean	SD	Mean	SD	Mean	SD
α_1	158	6 4	148	7 9	154	8 3
α_2	146	8 7	145	8 5	146	8 6
R/W	0 67	0 06	0 71	0 07	0 68	0 07
R/L	0 34	0 03	0 37	0 03	0 35	0 03
C/W	1 27	0 12	1 35	0 14	1 30	0 13
C/L	0 65	0 05	0 70	0 05	0 66	0 05
β	26	3 6	23	5 2	24	4 6
γ	15	2 8	15	3 6	15	3 1

Results

A strong linear correlation was found between the length of the talus and the width of the trochlea (r = 0 98 Fig 1) Both measures therefore seem to be applicable as reference measures in evaluating growth depending variables In the following the normal values obtained are related both to the length of the talus and to the width of the trochlea

The radius of the trochlear curvature obviously increases with growth It shows that the radius increases in proportion to the length of the talus (Fig 2) and the width of the trochlea In the autopsy and clinical materials combined the correlations between the radius of the trochlear curvature and these two variables were high (r = 0 99 and 0 97 respectively)

The mean of the index R/L in the autopsy material was 0 34 and in the clinical material 0 37 (Table 1) In the combined material the mean value was 0 35 and SD 0 03 For cases with a talar length of up to 57 mm the 95 per cent tolerance limits for R/L were calculated to be 0 29 and 0 42 (Table 2)

The mean index R/W was 0 67 in the autopsy material and 0 71 in the clinical material In the combined material the mean value was 0 68 and SD 0 07 The 95 per cent tolerance limits for R/W in cases with a trochlear width of up to 31 5 mm were 0 52 and 0 84 (Table 2)

The chord (C) of the trochlea was also linearly related to the length (L) of the talus (r = 0 99 Fig 3) and the width (W) of the trochlea (r = 0 97) The mean index C/L in the autopsy material was 0 65 and in the clinical material 0 70 In the combined

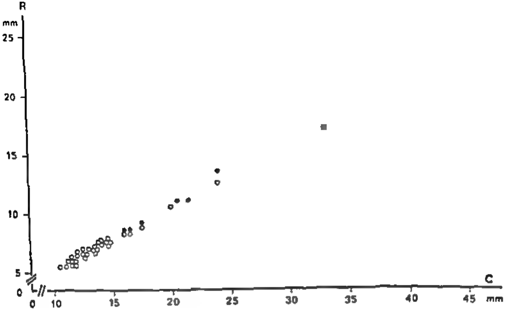

Fig 4 Linear correlation (r = 0 99) between radius (R) and chord (C) of trochlear curvature Symbols as in Fig 1

material the mean value was 0 66 and SD 0 05 The 95 per cent tolerance limits for cases with a talar length of up to 57 mm were 0 55 and 0 78 (Table 2)

The mean index C/W was 1 27 in the autopsy material and 1 35 in the clinical material In the combined material it was 1 30 with SD 0 13 The 95 per cent tolerance limits for cases with a trochlear width of up to 31 5 mm were 1 00 and 1 60 (Table 2)

The chord and radius of the trochlear curvature were linearly correlated (r = 0 99 Fig 4)

The central angle of the trochlear articular curvature was both calculated trigono metrically (sine $\alpha/2 = C/2R$) and measured directly on the film with a protractor By the trigonometric method the mean angle was 146 in the autopsy material and 145 in the clinical material In the combined material this value was 146 and SD 8 6 On direct measurement corresponding values of 158 148 154 and 8 3 were obtained (Table 1) Thus with the latter method a difference of about 10 was found between the mean values of the two materials The 95 per cent tolerance limits for cases with a talar length of up to 57 mm were 173 and 135 (Table 2)

No evident correlation was found between the central angle (α) of the trochlear curvature and either the length of the talus (Fig 5) or the width of the trochlea (r = −0 57 and −0 54 respectively)

The plantar deviation of the talonavicular joint (β) expressed as described was 26 on the average in the autopsy material and 23 in the clinical material In the

Table 2

Normal values for the talar variables expressed as tolerance limits which with 90 per cent confidence contain 95 and 99 per cent of a normal population respectively R = radius of trochlear curvature C = chord L = length of talus W = width of trochlea

Variable	Tolerance limits	
	95 per cent	99 per cent
Central angle (α) of the trochlear curvature	173 –135	179 –129
R/L	0 29–0 42	0 27–0 44
R/W	0 52–0 [illegible]	0 47–0 89
C/L	0 55–0 78	0 51–0 81
C/W	1 00–1 60	0 91–1 69
Plantar deviation (β) of talonavicular joint	14 –35	11 –38
Medial deviation (γ) of talonavicular joint	8 –22	6 –24

combined material the mean value was 24 with SD 4 6 The 95 per cent tolerance limits were approximately 14 and 35 (Table 2)

The medial deviation of the talonavicular joint (γ) expressed as described was about 15 on the average for both materials The mean value for the combined material was thus also 15 and SD 3 1 (Table 1) The 95 per cent tolerance limits for the medial deviation in cases with a maximum talar length of 57 mm and a maximum trochlear width of 31 5 mm were approximately 8 and 22 (Table 2)

The mean values of the clinical material were slightly but nevertheless significantly ($p < 0.05$) higher than those of the autopsy material for

the index R/L (difference 0 03)
the index R/W (difference 0 04)
the index C/L (difference 0 05)
the index C/W (difference 0 08)

The mean values of the clinical material were slightly but significantly ($p < 0.05$) lower than those of the autopsy material for the central angle of the trochlear curvature (difference 10) and the plantar deviation of the talonavicular joint (difference 3)

The length and width of the talus were greater on the average in the clinical than in the autopsy material The radius and chord of the trochlear curvature nevertheless appeared to be linearly related both to each other and to the length of the talus and the width of the trochlea throughout the material

The observed differences thus did not seem to be dependent on age in the age group 0 to 8 years The central angle of the trochlea and the plantar deviation of the talonavicular joint exhibited no clear correlation with the length of the talus or the width of the trochlea

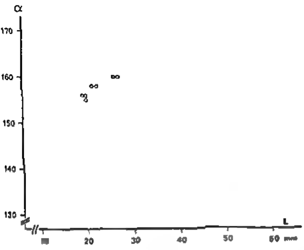

Fig 5 Central angle of trochlear curvature (α) plotted against length of talus (L) There is no obvious change in the angle with talar growth (r = −0 57) Symbols as in Fig 1

Discussion

Both the length of the talus and the width of the trochlea have advantages [illegible] reference measures for evaluation of other growth dependent talar variables Like the radius chord and central angle of the trochlear curvature—all growth-dependent variables—the length of the talus is measured on a lateral film of the ankle This means that the mutual relationships will be independent of magnification errors One disadvantage of using the length of the talus as a reference measure however is that this dimension is possibly affected more than the width of the trochlea when the talus [illegible] deformed On the other hand, measurement of the width of the trochlea will be somewhat less reliable than that of the talar length as this width is a smaller dimension and further the measurement points are more difficult to determine exactly However the trochlear width and talar length are strongly correlated

Measurement of the radius and chord of the trochlear curvature requires approximation of the curvature to the arc of a circle whose radius may be determined by a stencil In infants good approximation is obtained but in older children and adults the curvature of the trochlea deviates more from a circular shape The quotients R/L and R/W have been calculated to facilitate assessment of the trochlear curvature The radius increases with growth of the talus but its relations to the length of the talus and width of the trochlea are relatively constant [illegible] least up to a talar length of 57 mm or a trochlear width of 31 5 mm The index is easily calculated for the individual case and compared with the corresponding index for the normal material and its tolerance limits The same applies to the indices C/L and C/W

The normal value for the radius of the trochlear curvature may be calculated for a given talar length or trochlear width by multiplying the indices R/L and R/W by the measured values for the length and width of the trochlea respectively Corresponding calculations may be made for the chord (C) of the trochlea

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C/W	1 00-1 60	0 91-1 69
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SUMMARY

Simultaneous arthrography of the talocrural and talonavicular joints was performed on 32 normal feet from an autopsy material and corresponding examinations were conducted clinically on 22 feet with no signs of deformity The material comprised the age group 0 to 8 years A linear correlation was observed between the length of the talus and the width of the talar trochlea The radius and chord of the trochlear curvature increased proportionately with the talar length and trochlear width These relationships were expressed as indices by means of which the normal values for the radius and chord of the trochlea may be calculated for children up to 8 years of age The mean value standard deviation and tolerance limits were calculated for the central angle of the trochlear curvature and for the plantar and medial deviations of the talonavicular joint These angles were found to be virtually constant between the neonatal period and the age of 8 years

ZUSAMMENFASSUNG

Die gleichzeitige Arthrographie des Articulatio talo-cruralis und des Articulatio talonavicularis wurde an 32 normalen Fussen eines Sektionsmaterials und an 22 Fussen eines klinischen Materials ohne Zeichen einer Missbildung vorgenommen Die Altersgruppen zwischen 0 und 8 Jahren wurden untersucht Eine lineare Korrelation wurde zwischen der Lange des Sprungbeines und der Weite der Trochlea tali gefunden Der Radius und die Sehne der Kurvatur der Trochlea stiegen proportionell mit der Lange des Sprungbeines und der Weite der Trochlea Diese Zusammenhange wurden als Indizes ausgedruckt mit deren Hilfe die normalen Werte fur den Radius und die Sehne der Trochlea bei Kinder bis zu 8 Jahren berechnet werden konnen Die Mittelwerte die Standardabweichung und die Toleranzgrenzen fur den zentralen Winkel der Kurvatur der Trochlea und fur die plantare und mediale Abweichungen des Articulatio talo navicularis werden berechnet Diese Winkel erwiesen sich als fast konstant zwischen der Neonatalperiode und dem Alter von 8 Jahren

RESUME

Des arthrographies simultanees des articulations tibio-tarsiennes et astragalo-scaphoidiennes ont été faites sur 32 pieds normaux prélevés a l autopsie et les examens correspondants ont été pratiqués cliniquement sur 22 pieds ne présentant pas de signe de deformation Ce matériel concernait le groupe d age de 0 à 8 ans Les auteurs ont observe une correlation linéaire entre la longueur de l astragale et la largeur de la trochlée astragalienne Le rayon et la corde de la courbure trochleenne augmentent proportionnellement avec la longueur de l astragale et la largeur de la trochlée Les auteurs ont exprime ces relations sous forme d indices permettant de calculer les valeurs normales du rayon et de la corde de la trochlee pour les enfants jusqu à l age de 8 ans Ils ont calcule la valeur moyenne et la déviation standard et les limites de tolerance de l angle central de la courbure trochléenne et des deviations plantaire et interne de l articulation astragalo scaphoidienne Ils ont constaté que ces angles sont pratiquement constants entre la periode neonatale et l âge de 8 ans

The central angle (α) of the trochlea was calculated trigonometrically (sine $\alpha/2 = C/2R$) and also measured directly on the film with a protractor Both methods have their disadvantages In measurements of the chord and radius on small preparations with a precision of 9 5 mm poor differentiation is obtained for the central angle by the trigonometric method as $\alpha/2$ approaches 90 On the other hand in small preparations this angle is also difficult to measure directly The latter method is simpler and more practical for clinical use The central angle was found to be relatively constant The difference (about 10) observed between the mean values of the autopsy and clinical materials on direct measurement was not correlated to the size of the talus However this applies only to children up to 8 years of age It has been observed in anatomic investigations (BÖHM 1935) that the central angle is about 160 in newborn infants but about 120 in adults This reduction of the angle seems to take place gradually and was not demonstrated with certainty in the present material

Numerically small but significant differences were noted between the mean values of the autopsy and clinical materials for all variables except the medial deviation of the talonavicular joint Neither the autopsy nor the clinical material may be said to be randomly selected and it is possible therefore that the differences may have been real On the other hand they may have been due to dissimilarities in the methods of examination and measurement The films on the anatomic specimens were made under ideal conditions but the measurements on the films were more difficult than those on the clinical films Thus it cannot be decided with certainty whether the differences between the mean values of the two materials were due to selection or to differences in the arthrographic methods and measurement techniques However the discrepancies were small As the tolerance limits for the two materials and the combined material were in relatively good agreement the values given in Table 2 were considered acceptable as tolerance limits at the 95 per cent level

Conclusions

A linear correlation was found between the length of the talus and the width of the talar trochlea the radius of the trochlea (R) is proportional to the length of the talus (L) and to the width of the trochlea (W) These relationships may be expressed as the indices R/L and R/W the chord (C) of the trochlea is proportional to the length of the talus (L) and the width of the trochlea (W) These relationships may be expressed as the indices C/L and C/W these indices are suitable measures for testing deviations from the normal material the use of these indices obviates age tables for children under 8 years of age the central angle of the trochlear curvature is relatively constant at least up to the age of 8 years the plantar and medial deviations of the talonavicular joint are constant up to the age of 8 years

Normal limits are given for the different variables

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR A EVENSEN) ULLEVÅL SYKEHUS OSLO NORWAY

ARTHROGRAPHY OF THE KNEE JOINT WITH AMIPAQUE

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After injection of positive contrast medium into the knee joint a rapid decrease in attenuation of the medium occurs (FREIBERGER et coll 1966 WIENER 1967 HALL 1974) To ensure adequate demonstration of the intraarticular structures films must be taken without undue delay and complementary films are often unsatis factory Recent results in rabbits (JOHANSEN & BERNER 1976) indicate that the reduction in attenuation is slower with metrizamide (Amipaque Nyegaard) than with other media commonly employed in arthrography The present report consti tutes a clinical evaluation of Amipaque in arthrography of the knee

Material and Methods

The material consisted of 30 knee arthrographies of patients referred with possible meniscus rupture (Table 1) In 24 of the patients arthrography of a single knee joint was performed 2 had both knee joints examined with different contrast media and one had the same knee joint examined twice using different media with an 18 day interval Only patients in whom no more than 2 ml of joint fluid could be aspirated and who did not have a Baker s cyst were included in the material

Amipaque (290 mg I/ml) was compared with Urografin 60% (meglumine sodium diatrizoate 292 mg I/ml) A double blind technique was employed 10 ml of either

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Table 1

Sex age distribution (mean and range) and radiographic findings in menisci

Contrast medium	Women		Men		Menisci	
	No	Age (years)	No	Age (years)	Rupture	No rupture
Amipaque 290 mg I/ml	8	34 (15–54)	7	20 (15–31)	5	10
Urografin 60	6	39 (26–53)	9	26 (19–35)	[redacted]	[redacted]
Total	14	36 (15–54)	16	25 (15–35)	14	16

constrast medium selected at random was injected The knee was then exercised to disperse the medium evenly throughout the joint To aviod the bias of varying compression of the suprapatellar bursa no bandage was applied The circumference of the knee was measured before and immediately after injection and also after 1 hour In addition to the routine projections a p films for evaluation of contrast quality were exposed one and 5 min after injection and then at 5 min intervals up to 30 min and finally at one hour These films were later graded independently by 3 radiologists who had no knowledge of which contrast medium had been employed in each case The quality of delineation of the menisci was classified as either excellent or satisfactory The films were considered satisfactory instead of excellent when delineation of structures was no longer perfectly sharp although still adequate for diagnostic purposes

The patients were questioned about adverse symptoms during the examination and 1 hour after injection A questionnaire was filled in and returned by all the patients 2 days later The patients were instructed to remain immobile as far as possible during the day of the examination and to resume physical activities gradually during the two following days

For statistical evaluation Wilcoxon s ranking test for two samples was used

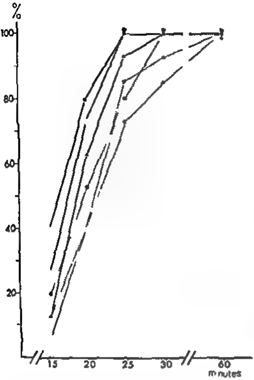
Results

All the films were of excellent quality initially but deteriorated rapidly in quality (Table 2) By 10 min only one of the arthrograms with Urografin and 4 to 7 of those

Table 2

Number of arthrographies with Amipaque and Urografin (in parentheses) considered excellent

Examiner	Time after injection of contrast medium			
	1 min	5 min	10 min	15 min
A	15 (15)	13 (11)	4 (1)	0 (0)
B	15 (15)	[redacted] (15)	6 (1)	0 (0)
C	15 (15)	13 (14)	7 ([illegible])	0 (0)



Percentage of arthrographies considered not satisfactory by three radiologists (symbolized by circle square and triangle) —— Urografin Amipaque

with Amipaque were still considered to be of excellent quality by the three examiners Duration of excellent and satisfactory quality was somewhat longer with Amipaque than with Urografin (Tables 2 3 Figure) The mean duration of satisfactory quality was 18 6 min$\pm$1 2 min (SEM) with Amipaque and 15 3 min$\pm$0 9 min (SEM) with Urografin (difference p $<$ 0 05)

In each of the 3 patients in whom both contrast media were used the duration of excellent and satisfactory quality was about 5 min longer with Amipaque

Both contrast media were well tolerated and there were no serious adverse effects The main complaints were slight to moderate pain and stiffness in the joint

Table 3

Number of arthrographies with Amipaque and Urografin (in parentheses) considered satisfactory

Examiner	Time after injection of contrast medium			
	15 min	20 min	25 min	30 min
A	14 (11)	9 (4)	2 (0)	1 (0)
B	13 (13)	9 (6)	4 (1)	1 (0)
C	12 (9)	7 (6)	3 (0)	0 (0)

Table 4

Number of cases with subjective adverse effects in the examined knee

Adverse effect	Amipaque 290 mgI/ml			Urografin 60		
	During examination	During 1st hour	During following 2 days	During examination	During 1st hour	During following 2 days
Pain						
Slight	1	3	5	—	1	8
Moderate	—	—	6	—	—	1
Severe	—	—	—	—	—	—
Stiffness						
Slight	4	6	7	1	6	9
Moderate	1	1	3	—	—	4
Severe	—	—	—	—	—	—

during the two following days and no significant difference could be observed between the two media (Table 4)

A very slight increase of the circumference of the knees (ca 1 mm) was measured immediately after injection of 10 ml contrast medium One hour after injection the circumference had increased slightly more than 3 mm with Amipaque and slightly more than 5 mm with Urografin with a difference averaging about 2 mm between the two groups (difference $p<0\ 10$)

Discussion

Amipaque is a water soluble triiodinated contrast medium which is non dissociable in solution Its osmolality is consequently low and has been measured to be about one third of that of ionic monomer contrast media with equal iodine concentration (HOLTERMANN 1973) As reduction of contrast concentration in a joint is partly due to dilution because of the osmotic effect of the contrast medium a diagnostically satisfactory concentration of Amipaque would be expected to be of longer duration than that of an ionic medium This was confirmed in arthrography of rabbits and the duration of contrast concentration can be correlated to the amount of joint effusion subsequent to injection (JOHANSEN & BERNER) The clinical results indicate that the duration of sharp delineation of the menisci is longer with Amipaque than with Urografin This might be explained by the difference in the amount of the reactive joint effusion which besides altering the attenuation also influences the rate of absorption Considerable individual variations were found which have also been observed with other contrast media (BJÖRK et coll 1970)

As Amipaque has a much lower neurotoxicity than other contrast media (SKALPE 1973 OFTEDAL 1975) less irritation of the synovial membrane in arthrography is to

be expected However microscopy of rabbit knees after contrast injection has not demonstrated any difference (JOHANSEN & BERNER) and the clinical result do not reveal any significant difference in symptoms The smaller joint effusions with Amipaque did not seem to make any difference

Contrast duration with Amipaque may be expected to be even longer by polymerization to increase its molecular size thereby reducing the rate of diffusion from the joint Epinephrine could also be added in order to reduce fluid movement across the highly vascular synovial membrane (HALL)

SUMMARY

In a double blind investigation 30 knee arthrographies were performed by injection of either Amipaque 290 mg I/ml or Urografin 60 % (292 mg I/ml) Both contrast media are well tolerated and give excellent initial contrast quality which deteriorates rapidly This occurs more slowly with Amipaque which has lower osmolality and causes less joint effusion

ZUSAMMENFASSUNG

In einer doppelt blind Untersuchung wurden 30 Kniearthrographien mit Injektion von entweder Amipaque 290 mg I/ml oder Urografin 60 % (292 mg I/ml) durchgefuhrt Beide Kontrastmittel waren gut verträglich und gaben ausgezeichnete initiale Kontrastqualitat welche schnell abnahm Diese Abnahme war langsamer bei Amipaque welches niedrigere Osmolalitat hat und weniger Gelenkergusse verursacht

RÉSUME

Dans une etude en double aveugle 30 arthrographies du genou ont ete faites par injection soit d Amipaque à 290 mg I/ml soit d Urografin 60° (292 mg I/ml) Ces deux moyens de contraste ont éte bien tolerés et donnent une excellente qualité de contraste initiale qui se deteriore rapidement Ceci se produit plus lentement avec l Amipaque qui a une osmolarite plus faible et cause moins d epanchement articulaire

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ANTERIOR INSTABILITY IN THE ANKLE JOINT FOLLOWING ACUTE LATERAL SPRAIN

A LINDSTRAND and W MORTENSSON

The lateral ligaments of the ankle are of the utmost importance for the stability of the joint The anterior talofibular ligament (in the following called the anterior ligament) is often ruptured in ankle sprains (BROSTRÖM 1964 CEDELL 1967) Persistent discomfort after ankle sprain is often due to defective healing of the ligament (BROSTRÖM 1966) Opinions differ about the treatment of the acute rupture This uncertainty at least partly reflects the lack of precise diagnostic criteria for this ligament lesion

When avulsion of the attachment of the ligament to the bone has occurred the diagnosis is usually made directly by radiographic demonstration of the bone fragment However the rupture usually occurs solely in the ligament tissue itself (BROSTRÖM 1964) In that event the diagnosis must be based on indirect evidence either the demonstration of displacement of the talus or the leakage of contrast medium from the joint at arthrography

After division of the anterior ligament of corpses the talus may be dislodged anteriorly (DEHNE 1933 ANDERSON et coll 1952 CASTAING & DELPLACE 1972) Under clinical conditions the displacement of the talus in an acute rupture is usually blocked by muscle defence evoked by pain but may be demonstrated by provocation This fact has been used to diagnose the rupture at clinical examination (LINDSTRAND 1976) and at radiography (ANDERSON et coll 1952 RUTH 1961 COUTTS & WOODWARD 1965 CASTAING & DELPLACE 1972 REICHEN & MARTI 1974) usually only

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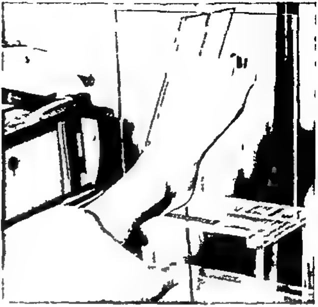


Fig 1 Equipment for examination of anterior stability of the ankle joint The patient's leg is raised supported in the heel and rotated inwards about 30 A sandbag hangs on the lower leg to provoke displacement The projection is checked by fluoroscopy

single cases are reported and the diagnostic value of radiography has not been adequately established

The present report deals with the diagnosis of acute rupture of the anterior ligament based on provoked anterior displacement of the talus demonstrated by radiography The purpose was to compare the degree of anterior displacement of the talus as demonstrated by radiography with the actual condition of the ligament as observed at operation and to define a suitable procedure for the radiography Preliminary results were reported previously (MORTENSSON & LINDSTRAND 1974)

Material

The material consisted of 68 patients 42 men and 26 women aged 14 to 47 mean age 26 years with an acute ankle sprain All had a history of indirect violence usually a supination trauma Only those patients were included who were considered to have anterior ligament rupture at physical examination (for a detailed description see LINDSTRAND 1976) No patients with fractures or signs of injured medial collateral ligaments were included

In all the 68 patients the surgical exploration was performed because of signs of ligament lesions irrespective of the results of radiography

Radiography

The examination was usually performed within 3 days after the injury Attempts were made to displace the talus anteriorly with the patient supine his leg raised

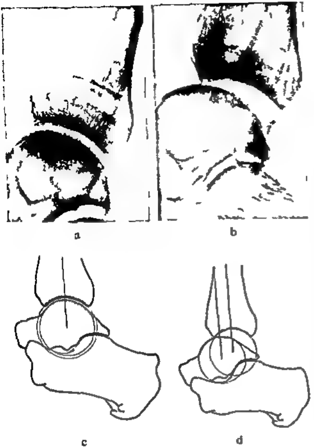


Fig. 2 Joint surfaces of tibia and talus run parallel and describe parts of concentric circles (a c). This symmetry disappears when the talus is displaced anteriorly (b d). With the aid of the transparent graph (Fig 3) a line is drawn through the middle of the lower tibia and the centre of the tibial circle (c). Another line paralleling this is drawn through the centre of the talar circle (d). The perpendicular distance between these two lines indicates the anterior displacement of the talus. The displacement index is obtained by dividing this distance by the sagittal length of the tibial joint surface (all measures in mm) and multiplying by 1 000. The displacement index is 275 in the case reproduced.

supported at the heel and rotated inwards about 30 and the ankle joint slightly plantar flexed (Fig 1). The need for complete muscle relaxation was explained to the patient. After the position of the joint had been checked by fluoroscopy lateral projections were obtained. The correct projection was defined as one in which the joint surface of the talar trochlea was projected tangentially (Fig 2 a). Six exposures were made according to the following schedule. The weight of the leg was allowed to act on the joint for about one minute and one exposure was made. An additional provocation effort was then made by application of a sandbag weighing 4 kg to the lower leg. The effect was registered by two exposures after half a minute and two minutes respectively. The same procedure was repeated after the area round the ligament had been locally anaesthetized by 5 to 10 ml carbocain 1% without vasoconstrictor agents. For comparison the uninjured ankle was also examined at the same time but without anaesthesia except in the first patients of the series.

All films not fulfilling the demands according to the definition of a true lateral projection were excluded. The patients with a complete examination schedule were used for the analysis of the influence of variations of the procedure on the results

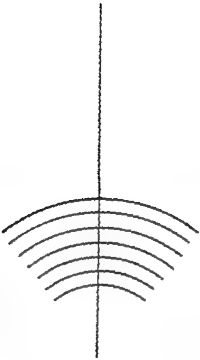


Fig 3 Transparent graph used to measure talar displacement The film is placed on the transparent graph so that the tibial joint surface covers the arc corresponding in size and so that the elongated radius passes through the middle of the lower tibia This line is transferred to the film which is then placed so that the talar trochlea covers a corresponding arc and the elongated radius parallels the first line This line is also drawn on the film and the distance between the two lines represents the anterior displacement of the talus (see also Fig 2 b d)

The total material was used to evaluate the sensitivity and specificity of the method and its diagnostic value In addition 11 patients were subjected to radiography in epidural anaesthesia in connection with the operation in 8 of these the uninjured ankle was also examined at the same time

Displacement index In lateral projection the joint surfaces of the tibia and the talus may be considered to describe arcs of concentric circles (Fig 2 a c) This congruity disappears when the talus is displaced (Fig 2 b d) The distance between the centres of these two circles indicates the degree of anterior displacement of the talus (Fig 2 d) A transparent graph was used for the calculation (Fig 3) Correction for varying geometric enlargement was made by dividing the measured anterior displace

Table 1

The condition of the anterior talofibular ligament at operation for acute ankle sprain

Group 1	Normal	11
Group 2	No rupture but abnormal macroscopic appearance	5
Group 3	Acute total rupture	5*

In 5 patients combined with a complete and in 5 with an incomplete acute rupture of the calcaneofibular ligament

Table 2

Anterior displacement of the talus in ankles without rupture of the anterior talofibular ligament All had recently sustained ankle sprains and had clinically suggested ruptures At operation the ligament was found to be normal in 11 (Group 1) and to have abnormal appearance in five (Group 2) Not all the ankles were examined according to the complete examination schedule The degree of anterior displacement was expressed in an index

	Group 1				Group 2			
	Range	Mean	SD	n	Range	Mean	SD	n
A Without local anaesthesia								
1 No additional provocation	0–63	15	21	9	0–50	33	[illegible]8	3
2 Additional provocation 1/2 min	0–65	33	29	6	0–233	90	101	4
3 Additional provocation 2 min	0–85	45	43	3	23–132	78	76	2
B With local anaesthesia								
1 No additional provocation	0–103	37	41	8	26–200	86	78	4
2 Additional provocation 1/2 min	0–87	49	55	7	100–196	159	68	3
3 Additional provocation 2 min	0–205	76	60	9	67–1[illegible]5	99	30	3
Significance of the differences	A1 v A3 not significant B1 v B3 not significant A1 v B2 not significant				A1 v A3 *not significant* B1 v B3 not significant A1 v B1 not significant			

ment by the sagittal length of the tibial joint surface the quotient being multiplied by 1 000 The result was referred to as the displacement index No correction was made for the various sizes of the tibial joint surface Only the anterior displacement was measured the concomitant medial rotation and the distal displacement of the talus were not considered

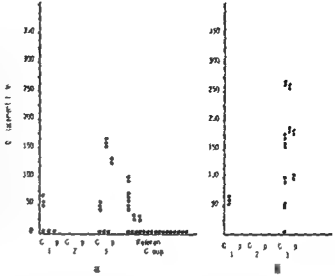
Statistical methods

In constructing Table 3 differences between displacement index within the groups were estimated by the t test for paired observations Otherwise quantitative differences were estimated by conventional t test for unpaired observations Confidence intervals for differences were made in the way described in Geigy s Scientific Tables (1971) In the text a 95 per cent confidence interval is given within brackets following the percentage number

Results

Clinical results At exploration an acute rupture of the anterior talofibular ligament was most frequent An additional partial or total rupture of the calcaneofibular ligament was found in one fifth of these cases Two had an isolated rupture of the anterior tibiofibular ligament If no fresh ligament rupture existed a haematoma in the soft tissue was usually found

Fig 4 Maximum displacement index for each ankle when examined (a) without and (b) with local anaesthesia irrespective of whether additional provocation load was applied to the lower leg or not Group 1 Normal anterior talofibular ligament Group 2 Non ruptured ligament with macroscopically abnormal appearance Group 3 Ruptured ligament Reference group The uninjured ankles of the patients in Groups 1 to 3



The material was classified into 3 groups according to the condition of the anterior talofibular ligament as observed at operation (Table 1)

Results of radiography The series was complete in 24 of the ankles in group 3 (ruptured anterior ligament) and in 24 of the uninjured ankles (reference group)

When the examination was made without anaesthesia and without load provocation the mean value for the displacement indices did not differ significantly in the various groups (Tables 2 3) After a load had been applied to the lower leg the displacement increased in cases with an abnormal anterior ligament (groups 2 3) With increased provocation force in addition to local anaesthesia the displacement further increased particularly when the force was applied for two minutes

Increasing the provocation force caused a greater anterior displacement in the ankle joint than did local anaesthesia only (Table 3) The combination of both procedures increased the displacement

The mean maximum displacement index for all cases in group 3 when examined without anaesthesia was 128 for isolated anterior talofibular ruptures and also for anterior talofibular combined with partial calcaneofibular ruptures The combined anterior talofibular and total calcaneofibular ruptures had a mean value of 156 In local anaesthesia these mean maximum displacement indices were 182 for isolated anterior ruptures 140 for anterior and partial calcaneofibular and 225 for anterior and total calcaneofibular ruptures

All 9 patients with an intact anterior ligament had a displacement index less than 90 when examined without local anaesthesia (Fig 4 a) This value was therefore considered as the normal upper borderline Based on this criterion the sensitivity of the examination method was low in diagnosing acute rupture of the anterior ligament when the examination was made without local anaesthesia only about two thirds of the cases with ruptured anterior ligament had displacement indices above 90

Table 3

Anterior displacement of the talus in 24 ankles with acute ankle sprain and rupture of the anterior talofibular ligament confirmed at operation (Group 3) and in 24 uninjured ankles (reference group). All were examined according to the complete examination schedule. The degree of anterior displacement was expressed in an index

	Group 3				Reference Group			
	Range	Mean	SD	n	Range	Mean	SD	n
A Without local anaesthia								
1 No additional provocation	0–94	26	33	24	0–95	16	25	24
2 Additional provocation 1/2 min	0–258	87	69	24	0–200	33	55	24
3 Additional provocation 2 min	48–303	123	64	24	0–200	48	60	24
B With local anaesthesia								
1 No additional provocation	9–188	72	48	24				
2 Additional provocation 1/2 min	0–259	138	70	24				
3 Additional provocation 2 min	105–296	177	52	24				
Significance levels of differences between mean values								
	A1 v A2 p<0.001				A1 v A2 p<0.05			
	A2 v A3 p<0.01				A2 v A3 p<0.05			
	B1 v B2 p<0.001							
	B2 v B3 p<0.001							
	A1 v B1 p<0.001							
	A2 v B2 p<0.025							
	A3 v B3 p<0.001							

(Fig 4 a) When the examination was carried out under local anaesthesia 9/10 were correctly diagnosed (Fig 4 b) However with the same criterion there would be a large fraction of false positive results in group 2 and also to some extent in group 1 (Fig 4 b) Similarly in the reference group examination without local anaesthesia but with additional load showed that 1/8 had displacement indices higher than 90 (Fig 4 a)

All cases with rupture of the anterior ligament examined under epidural anaesthesia demonstrated marked displacement This usually appeared before any additional force was exerted on the lower leg and increased following provocation (Fig 5) The displacement index for the reference ankles was higher than 90 in 3/8 (Fig 5) Only 2 patients with confirmed normal anterior ligament were examined under epidural anaesthesia The displacement indices were 57 and 94 even under increased provocation

Based on the examination of all ankles with a history of acute ankle sprain and clinical evidence of an acute rupture of the anterior ligament the predictive value of a positive examination result (index 90 or higher when examined under local anaesthesia irrespective of whether or not additional provocation force was used) was 0.9 (0.76 to 0.96) and of a negative examination result 0.6 (0.35 to 0.87)

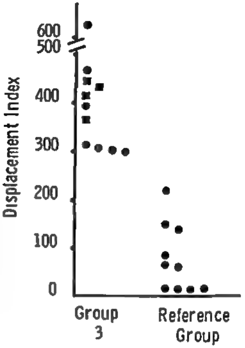


Fig 5 Maximum displacement index at examination of 11 ankles in epidural anaesthesia obtained under manual provocation In 4 ankles the index could not be calculated exactly because the projections were oblique In these ankles indicated by squares the index is calculated roughly Group 3 Confirmed rupture of the anterior talofibular ligament Reference group The uninjured contralateral ankles (8) and 2 ankles with confirmed normal ligament

Discussion

Not only the joint capsule and ligaments but also the muscles adjacent to the joint and their tendons contribute to the stability of the ankle joint It is therefore important for the patient to be prevailed upon to relax the muscles as completely as possible in the lower leg when the ankle joint is examined for instability The experience suggests that failure to provoke anterior displacement of the talus following acute rupture of the anterior ligament is due to deficient muscle relaxation This statement is supported by the fact that marked displacement occurred invariably when muscle tension was eliminated by the use of epidural anaesthesia Moreover fluoroscopy of tense patients made it possible to observe a momentary displacement when manual pressure was suddenly exerted on the lower leg Staples (1975) also found the examination method to be of limited value when applied without anaesthesia

The number of false negative results is thus reduced or perhaps even eliminated by a correct examination method However the false positive results are more disconcerting A displacement index higher than 90 appeared in two ankles with a confirmed normal anterior ligament (group 1) at examination under local anaesthesia One of these patients also had a large index on the other side Various degrees of laxity in the ligament thus seem to exist normally which contribute to the number of false positive results of the examination

The abnormal appearance of the anterior ligament in group 2 is considered to be

due to previous ligament injuries Most ankles in this group presented marked dis placement

Most of the ankles in the reference group had a displacement index less than 90 when examined in epidural anaesthesia Moreover all 3 in the reference group with an index above 90 had had previous ankle injury The indices of the two with a confirmed intact anterior ligament and examined in epidural anaesthesia were also less than and slightly higher than 90 respectively Therefore it is considered that a displacement index higher than 90 on the uninjured side often depends on previous ligament injuries or ligament laxity Similar experience was reported by COUTTS & WOODWARD (1965) In a reference group of 33 ankles they succeeded in provoking anterior displacement in 13 9 of them being known to have had previous ankle injuries

Using a heavy provocation load LAURIN & MATHIEU (1975) generally found an anterior displacement of the talus of about 4 mm in adults with no history of ankle trauma The degree of instability was equal on both sides CASTAING & DELPLACE (1972) consider that the normal anterior instability does not exceed 5 mm LANDEROS et coll (1968) found the normal separation during the anterior drawer test to be 2 5 to 3 0 mm These results agree with the present findings a displacement index of 90 corresponds to a talar displacement of about 3 mm The diagnostic ability of the present examination method was superior to that reported by COUTTS & WOODWARD (1965) When they performed the examination in peroneal nerve blockade anterior displacement was observed in 16/22 ankles with recent tears of the lateral ankle ligaments Further comparison cannot be made as they did not specifiy their defini tion of anterior displacement of the talus nor the precise extent of the ligament in juries At radiography DUQUENNOY et coll (1975) found that the talus could be displaced in about half of 104 patients with operatively confirmed acute rupture of the anterior ligament No measurements of the displacement were given A few authors have reported that the talus was not displaced despite a rupture of the anterior ligament (STEELE 1955 RUTH 1961) At least partly this may depend on the examina tion method with the foot in forced equinus which renders muscle relaxation more difficult

In experiments on corpses CASTAING & DELPLACE (1972) found an anterior dis placement of 8 to 10 mm when the anterior talofibular ligament was sectioned 10 to 15 mm when both the anterior and the posterior ligaments were sectioned 12 mm when the anterior talofibular and the tibiotalar ligaments and the anterior capsule were sectioned and 15 mm when the anterior and posterior talofibular the calcaneo fibular and the anterior tibiotalar ligaments were sectioned LANDEROS et coll (1968) observed in a clinical material a displacement of 4 to 6 mm

These observations concerning combined anterior and distal translations are comparable to the pre ent results

SUMMARY

The relation between anterior instability in the ankle joint and rupture of the anterior talofibular ligament was investigated in patients with acute ankle sprains Various techniques were used to provoke anterior displacement of the talus The actual condition of the anterior talofibular ligament was assessed at op ration The appropriate radiographic method was defined and its value in diagnosing an acute rupture of the anterior talofibular ligament was assessed

ZUSAMMENFASSUNG

Der Zusammenhang zwischen der vorderen Instabilitat im Knochelgelenk und der Ruptur des vorderen talo-fibularen Ligaments wurde bei Patienten mit akuten Verrenkungen des Knochelgelenks untersucht Verschiedene Techniken wurden verwendet um eine Verschiebung des Sprungbeines nach vorne zu provozieren Der wirkliche Befund des vorderen talo-fibularen Ligaments wurde bei der Operation beurteilt Die geeignete rontgenologische Untersuchungsmethode und deren Wert zur Diagnose einer akuten Ruptur des vorderen talo-fibularen Ligaments wurden festgestellt

RESUME

La relation entre l instabilité antérieure dans la cheville et la rupture du ligament astragalo péronier antérieur a été étudiee chez des malades atteints d entorse aigue de la cheville Differentes techniques ont été utilisées pour provoquer un déplacement en avant de l astragale L etat reel du ligament astragalo-péronier antérieur a été examiné en cours d opération Les auteurs ont défini la méthode radiographique appropriée et ont déterminé son intérêt dans le diagnostic de la rupture aiguë du ligament astragalo-péronier antérieur

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Book review

AN ATLAS OF NORMAL VERTEBRAL ANGIOGRAMS By Paul Ross and George H du Boulay 126 pages 108 illustrations Butterworths London 1976 Price £ 15 00

The present atlas of vascular anatomy and normal variants within the vertebro basilar territory has been arranged logically into a structure of considerable didactic attraction The first section is a condensed description of the course and anatomical relationships of arteries and veins including nine perspective diagrams of the posterior fossa and diencephalon and a short list of pertinent references to original works

The main section consists of full size angiographic subtractions in arterial and venous phase in straight a p Towne s and lateral projections from 22 clinical angiographies In all the angiographic reproductions the vessels have been extensively labelled with numbers Outfolding keys red for the arteries and blue for the veins facilitate identification of the numbered vessels On the page facing every a p or Towne s projection a corresponding lateral has been placed Thus considerable effort has been devoted to rendering the atlas easy and effective to use

Two imperfections prevent the book from grading first class The quality of reproduction probably does not do justice to the original angiographic subtractions in too many of the illustrations there is a lack of contrast definition and detail pro tanto creating difficulties for the reader

The second disadvantage is the printing of the extensive numerical labelling directly on the angiographic illustrations which is often quite disturbing In clinical angiography vessels do not come out labelled a similar situation i e angiographic images available also in the unlabelled state would probably be more useful to the student learning to master orientation in an unknown country The best solution would probably be to print the labels separately on transparent overlays or even (transparencies possibly being costly) on explanatory drawings in parallel

In spite of these shortcomings the atlas is a very useful book providing a comprehensive survey of pertinent vascular anatomy It affords good remedy for the state of frustration familiar to anyone getting entangled in the Byzantine detail (quoting the authors) that is characteristic of much recent work in posterior fossa vascular anatomy One should indeed be grateful to highly qualified experts who take time and trouble to compile a simplified account of such a complex subject matter without losing sight of clinically significant features

Ulf Bergvall

FROM THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF G F SALTZMAN) ORTHOPAEDIC SURGERY (DIRECTOR PROF R LEMPERG) AND PATHOLOGY (DIRECTOR PROF F BERGMAN) UNIVERSITY OF UMEÅ S 901 85 UMEÅ SWEDEN

ANGIOGRAPHY IN GIANT CELL TUMOURS OF BONE

B LUNDSTROM R LORENTZON S E LARSSON and L BOQUIST

Genuine giant cell tumours of bones often give rise to difficult clinical problems because of their anatomic location the high frequency of local recurrences and the difficulty of predicting the clinical course with respect to the risk of malignant course Previously microscopic grading or cytologic assessment of the degree of malignancy was found to be of no prognostic value (LARSSON et coll 1975) which is in conformity with other reports (DAHLIN et coll 1970 GOLDENBERG et coll 1970) This tumour has a frequency of local recurrence of 42 per cent for all tumours and 66 per cent for those located near the knee joint and wrist A malignant course was noted in 11 3 per cent of the cases the majority in patients with the tumour located in the distal femur for which site the mortality was 36 per cent (LARSSON et coll)

Among the bone tumours that may be difficult to distinguish from genuine giant cell tumours at conventional skeletal radiology are aneurysmal bone cysts non ossifying fibromas simple unilocular bone cysts and a few more rare skeletal abnormalities Even though the microscopic differentiation of these tumours as well as other bone lesions with a large number of giant cells has been described in detail (JAFFE et coll 1940 SPJUT et coll 1970) difficulties still exist in differentiating a genuine giant cell tumour from a so called giant-cell variant The most common false diagnoses are aneurysmal bone cysts and non ossifying fibroma (LARSSON et coll) Whereas a non ossifying fibroma is an entirely benign lesion local recurrences with a frequency of 20 per cent have been reported after surgery of aneurysmal

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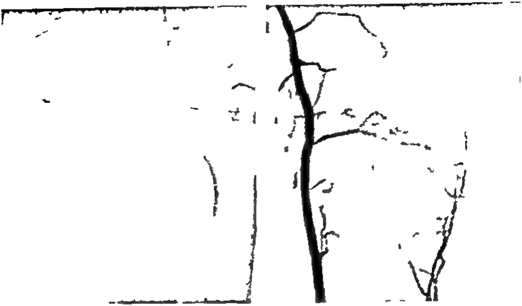


Fig. 1 Giant-cell tumour a) Conventional film of the wrist b) early c) middle arterial phase Highly vascular tumour with pooling of contrast medium in the early arterial phase Early filling of large veins Fairly homogeneous and prolonged accumulation of medium in the tumour A thin hypervascular soft tissue component surrounds a large part of the tumour

bone cysts They never degenerate malignantly except possibly after irradiation (LICHTENSTEIN 1957 TILLMAN et coll 1968)

Reports on angiography of these tumours are scarce but seem to indicate that giant-cell tumours and aneurysmal bone cysts have a similar angiographic appearance Since the treatment and prognosis are so different in these types of tumour a more detailed analysis of the angiographic appearances of genuine giant-cell tumours was

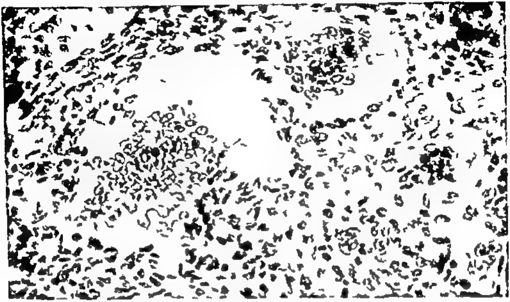


Fig 2 Same case as in Fig 1 Microscopy Rather monomorphous stromal cells and giant cells with vacuolated cytoplasm and mainly centrally situated nuclei The largest cell possesses a great number of oval or rounded hypochromatic nuclei with distinct nucleoli van Gieson ×440

performed with the intention to elucidate whether they may be distinguished angiographically from giant-cell variants such as aneurysmal bone cysts If an assessment of malignancy should be possible this might serve as a guide for therapy and have prognostic significance

Material The genuine giant-cell tumours consisted of 2 cases treated at another hospital and 7 cases in the Umea region observed after 1968 The cases were included in the series only when re examination of the microscopic material (performed by L B) and follow up confirmed the diagnosis The demands upon the angiographic examinations were that the quality of the films was high that subtraction was possible and that as a rule 2 projections were used In the total of 9 cases of genuine giant-cell tumours included 5 were males and 4 females between 17 and 68 years In 6 cases the tumour was located adjacent to the knee joint in 2 in the distal radius and in one in the iliac bone Six cases of aneurysmal bone cyst fulfilling the same demands with regard to microscopy and angiography were also included 2 males and 4 females aged 10 to 32 years In 4 cases the tumour was located near the knee joint and in 2 cases at the proximal end of the femur Also included is a case of non ossifying fibroma located in the distal tibia of a 40-year old woman

Microscopy All original slides from all patients in the series were re-examined and additional material was sectioned and stained with haematoxylin eosin van Gieson s stain periodic acid Schiff phosphotungstic acid haematoxylin and Laidlaw s silver impregnation

Fig. 3. Giant-cell tumour. a) Conventional film 14 years previously. b) After several operations with local recurrence. c) Early. d) late arterial phase. Hypervascularity with homogeneous accumulation of contrast medium, large abnormal veins early filled. Encasement of small arteries (→). The tumour is surrounded by a thick, hypervascular soft tissue component.

Angiography. Selective injection into the femoral or axillary artery was used with an exposure rate of 2 films per second in the arterial phase. Drugs were not used in connection with angiography. Twofold magnification angiography was performed in 2 cases using a microfocus tube. The vascularity of the tumour, appearance of arteries and veins, accumulation of contrast medium within the tumour, arteriovenous

Fig 4 Giant-cell tumour In the caudal lateral part evident hypervascularity with non homogeneous accumulation of contrast medium and early filling of veins partly in the soft tissue component Other parts are less vascular

shunts and soft tissue components were evaluated Special significance has been attached to abrupt termination or encasement of arteries and the presence of venules crossing at right angles to the venous outflow

Results

Microscopy Grading of the giant-cell tumours according to JAFFE et coll (1940) gave the following results grade 1 in 2 cases grade 2 in 4 cases and grade 3 in 3 cases

Most giant-cell tumours were composed of solid sheets of medium sized polygonal or more seldom spindle shaped cells with a round d centrally or occasionally peripherally localized nucleus A rather distinct and moderately enlarged nucleolus was seen The chromatin was rather finely dispersed and the nuclear membranes were easily discerned The stromal cells exhibited a moderate amount of cytoplasm occasionally vacuolated The cell boundaries were usually indistinct In addition to the stromal cells there was a large number of diffusely scattered giant cells usually with an irregular outline The number of nuclei varied considerably Some giant cells possessed more than 100 nuclei often more or less centrally located (Fig 2) The nuclei were essentially similar to those of the stromal cells The cytoplasm was occasionally vacuolated Many giant cells possessed cytoplasmic processes Osteoid tissue was observed in some tumours and in a few cases reactive bone formation at the periphery of the tumour Aggregates of foam cells were occasionally encountered

Fig. 5 Giant-cell tumour in the distal femur Middle of the arterial phase Local hypervascularity and local soft tissue component

The aneurysmal bone cysts were microscopically characterized by blood spaces of varying sizes (Fig 9) occasionally with a cystic appearance They contained blood corpuscles and were surrounded by fibrous or granulation tissue Endothelial like cells were seen rather seldom around the blood spaces The fibrous tissue contained inflammatory cells and areas of osteoid tissue Extravasated blood and haemosiderin pigment were frequently observed in the fibrous tissue Multinucleated giant cells were seen with varying frequency in the aneurysmal bone cysts usually close to the blood spaces The non-ossifying fibroma was composed of whorls of connective tissue of monomorphous appearance (Fig 10 c) Small blood vessels but no large blood spaces were encountered A few multinucleated giant cells were identified aggregated in small groups They were smaller than those of the giant-cell tumours and aneurysmal bone cysts and usually possessed small somewhat irregular and dense nuclei and a sparsely distributed amount of cytoplasm of high density

Angiography

Genuine giant-cell tumours of bone In all 9 cases the tumours were hypervascularized An increased number of tortuous vessels was always found in the osteolytic part of the tumour This part of the neoplasm was always surrounded by a hypervascularized zone of varying width It was often difficult to determine exactly whether the blood vessels were located in the lytic part of the tumour or only surrounded it like a hypervascularized capsule Two of the cases were extremely rich in vessels

Fig 6 Giant-cell tumour The tumour is fairly vascular and exhibits essentially homogeneous accumulation of contrast medium and early filling of large veins in the soft tissues medial to the osseous part of the tumour

(Fig 1) There was also a distinct accumulation of contrast medium within the tumour in all cases most frequently in the early arterial phase In 5 of the cases the pooling of contrast medium was homogeneous throughout the tumour (Fig 3) Arteriovenous fistulas existed in all cases and the more vascular the tumour the larger and more evident were the shunts A highly vascularized soft tissue component of varying width existed in all cases Sometimes this component was thin and surrounded the whole tumour like a capsule (Fig 1) sometimes it was wide all around the tumour (Fig 3) and sometimes it was wide only locally (Fig 4) In a few cases there was a local hypervascular soft tissue component adjacent to a fracture with callus (Fig 5) Pooling of contrast medium was observed in all cases as a rule in the early arterial phase (Fig 1) The irregular pools were fairly small and well outlined An entirely convincing demonstration of irregularly and fairly suddenly tapering blood vessels in the tumour and abrupt termination of arteries has not been possible but were suggested in some cases (Fig 3) In 7 of the 9 cases large tortuous veins usually filled at an early stage were observed most frequently at the periphery of the tumour They either surrounded large parts of it (Fig 3) or were more locally distributed (Fig 6) These large veins made it difficult to assess the presence of any smaller veins coursing at right angles to the regular venous outflow which has been stated to be a criterion of malignancy in certain varieties of bone tumours (Lester et coll 1971) No definite veins of this type were demonstrated No correlation between the microscopic grading and the hypervascularity or the other angiographic abnormalities were found The hypervascular soft tissue component was widest and most distinct in the single case in the series exhibiting definite malignancy with metastases and in the case with a local recurrence 14 years after the onset of the disease

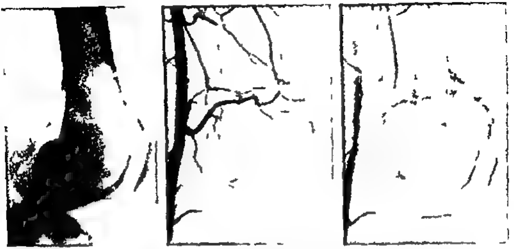
Fig 7 Aneurysmal bone cyst a) Fracture through the tumour region in the proximal femur b) Hypervascularity and diffuse pooling of contrast medium in the early arterial phase c) Early filling of large veins partly surrounding the tumour like a thin edging

Aneurysmal bone cyst These 6 cases were generally less hypervascularized than the giant-cell tumours but there were some cases with marked hypervascularity fairly intensive accumulation of contrast medium and early filling of large veins as in the case illustrated in Fig 7 However this case had fracture in a state of healing Homogeneous accumulation of contrast medium was never encountered and patchy tumour filling often occurred somewhat later in the course of angiography than in the giant cell tumours Arteriovenous fistulas existed in 3 cases Pooling of contrast medium was demonstrated in 3 cases and occurred later in the arterial phase and appeared to be more irregular with more blurred outlining than in the giant-cell tumours However one case had the same angiographic appearance as the giant cell tumours (Fig 8)

Non ossifying fibroma One case is included because it was suggested from the conventional films to be a case of giant-cell tumour In the large partly multilocular cystic lesion in the distal tibia few if any vessels were filled at angiography (Fig 10)

Discussion

The differentiation of genuine giant-cell tumours from other so-called giant-cell lesions usually presents no difficulties when all clinical radiologic and microscopic findings are taken into consideration However in general practice differential diagnostic problems may be encountered in occasional cases (LARSSON et coll) The light microscopic appearance of the giant-cell tumours aneurysmal bone cysts and the non ossifying fibroma of the present series conforms to general descriptions



a b c

Fig 8 Aneurysmal bone cyst a) Conventional film b) early c) late arterial phase Moderately vascular tumour Irregular pooling of contrast medium in the late arterial phase with thin non homogeneous accumulation of medium Early filling of small veins at the periphery of the tumour

Only isolated individual cases of angiography of giant cell tumour have been reported hitherto (FARIÑAS 1937 DOS SANTOS 1950 CALDOS 1953 SCHOBINGER & STOLL 1957 MUCCHI et coll 1966 DIETHELM et coll 1969 GREMMEL & BECHER 1970) The most constant abnormalities reported have been accumulation of the contrast medium in the tumour homogeneous over a prolonged period of time and in some cases early filling of the veins STRICKLAND (1959) and LESTER et coll both described 3 cases of giant cell tumour in which the angiographic appearance varied YAGHMAI et coll (1971) published 8 cases of giant cell tumour and 4 cases of aneurysmal bone cyst and reported that hypervascularization and arteriovenous shunts were encountered in both benign and malignant giant cell tumours as well as in aneurysmal bone cysts Apart from these only a small number of reports have been published on angiography of aneurysmal bone cysts (SCHOBINGER & STOLL LINDBOM et coll 1961 MUCCHI et coll PROBST 1973) The bone cyst was described as rather poorly vascularized and diffuse accumulation of contrast medium in the late arterial phase was common RING et coll (1972) reported a case of aneurysmal bone cyst exhibiting hypervascularity and arteriovenous shunts

In the present 9 cases of genuine giant cell tumour the period of observation is 4 to 15 years in 3 cases and 1 to 3 years in 6 Thus in most cases the period of observation is rather short to allow a conclusive assessment of recurrences and malignant course Only one case had metastases and one a local recurrence In both of these cases there was a broad highly vascular soft tissue component which was larger than in the other cases However in other respects the angiographic appearance hardly differed from that of the other tumours All cases were fairly or exceedingly vascular and exhibited more or less homogeneous accumulation of contrast medium in the

Fig 9 Same case as in Fig 8 Blood spaces outlined by fibrous (F) or granulation (G) tissue with an *indistinct endothelial lining Haematoxylin-eosin* × 80

early arterial phase Arteriovenous shunts of varying sizes were present in all cases No correlation could be demonstrated between microscopic grading and hypervascularity or arteriovenous shunts Certain other vascular abnormalities have been considered to constitute more significant signs of malignancy e g abrupt termination or encasement of tumour blood vessels or straight veins coursing at right angles to the normal venous outflow (STRICKLAND LESTER et coll NEY et coll 1972) The possibility of performing malignancy gradings on these grounds was estimated to be limited in the present material

As a rule the 6 cases of aneurysmal bone cyst were less vascular but hypervascularity did occur In some cases the appearance closely resembled giant-cell tumours In most cases there was sparse diffuse filling of slightly irregular lacunae of unequal sizes with a more blurred outline than in the genuine giant cell tumours At microscopy aneurysmal bone cysts are found to be highly vascular but the vascular bed evidently participates only to a slight extent in the circulation It is possible that some of these blood filled spaces may fill with contrast medium during angiography Previously reported cases have generally been poorly vascularized but there are also reports on hypervascular cases and large arteriovenous shunts in which it was not possible to distinguish between aneurysmal bone cysts and giant cell tumours or to grade any existing malignancy (STRICKLAND LESTER et coll NEY et coll) It is true that LINDBOM et coll reported mainly poorly vascularized cases but they indicated that a differential diagnosis of these tumours was not possible It is evident that

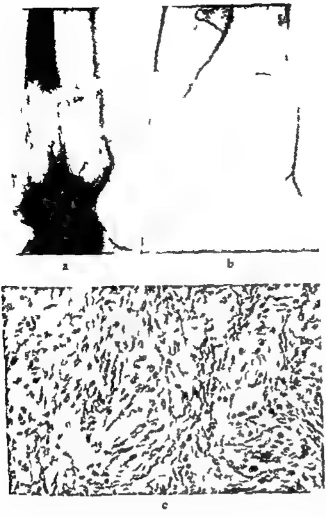


Fig 10 Non ossifying fibroma a) b) Poorly vascularized large cystic tumour c) Whorls of monomorphous spindle shaped cells van Gieson 340

hypervascularity accumulation of contrast medium and arteriovenous fistulas occur both in malignant and benign genuine giant-cell tumours as well as in certain cases of aneurysmal bone cyst In these cases a differential diagnosis would seem to be impossible on the basis of angiography On the other hand it is obvious that the size of the soft tissue component is of prognostic significance in cases of genuine giant cell tumour (LARSSON et coll) If a tumour on conventional skeletal films resembles a genuine giant cell tumour but at angiography is poorly vascularized and devoid of both arteriovenous shunts and a soft tissue component the lesion is probably an aneurysmal bone cyst In the case of non ossifying fibroma conventional films and microscopy should generally provide enough information for the correct diagnosis If some doubts exist angiography may be valuable (Fig 10) as this benign bone lesion is poorly vascularized (YAGHMAI et coll) Fractures are common in both of

these types of tumour which influence the angiographic appearance making it indistinct and ambigous. A certain degree of local hypervascularity adjacent to the fracture and a small hypervascular soft tissue component in the vicinity were found both in cases with and without callus. To direct a biopsy on the basis of angiographic findings would probably be pointless since the degree of hypervascularity hardly reflects the degree of malignancy.

The main results indicate that a differential diagnosis between genuine giant cell tumours and aneurysmal bone cysts is possible in some cases only. This is consistent with the statements of YAGHMAI et coll. The prognostic significance of the soft tissue component in genuine giant cell tumours has previously been pointed out (LARSSON et coll.). Angiography offers the possibility of assessing the size and extent of this component more exactly. In a little more than half of the cases aneurysmal bone cysts appear to be relatively poorly vascularized, are devoid of a soft tissue component and arteriovenous fistulas. These cases may be differentiated from genuine giant-cell tumours.

SUMMARY

The angiographic appearance of 9 cases of genuine giant-cell tumour of bone, 6 cases of aneurysmal bone cyst and one case of non ossifying fibroma is described. Differential diagnosis would appear to be possible to a certain extent. The non ossifying fibroma was poorly vascularized. The genuine giant-cell tumours were hypervascularized as well as some of the aneurysmal bone cysts making a differential diagnosis in these cases impossible. On the other hand, a poorly vascularized tumour devoid of soft tissue component and arteriovenous fistulas is probably an aneurysmal bone cyst. A hypervascular soft tissue component is of great prognostic value in cases of genuine giant-cell tumour.

ZUSAMMENFASSUNG

Das angiographische Bild von 9 Fällen mit echten Riesenzelltumoren des Knochens, von 6 Fällen mit einer Knochenzyste bei einem Aneurysma und von einem Fall mit einem nicht verknöchernden Fibrom wird beschrieben. Die Differentialdiagnose scheint bis zu einem gewissen Mass möglich zu sein. Das nichtverknöchernde Fibrom war wenig vaskularisiert. Die echten Riesenzelltumoren waren hypervaskularisiert, ebenso wie einige der Knochenzysten bei einem Aneurysma, was die Differentialdiagnose in diesen Fällen unmöglich macht. Auf der anderen Seite ist ein schlecht vaskularisierter Tumor ohne Beteiligung einer Weichteilkomponente und arteriovenöse Fisteln wahrscheinlich eine Knochenzyste bei einem Aneurysma. *Die hypervaskularisierte Weichteilkomponente ist von grossem prognostischen* Wert bei Fällen von echten Riesenzelltumoren.

RESUMÉ

Les auteurs décrivent les aspects angiographiques de 9 cas de véritable tumeur osseuse à cellules géantes, 6 cas de kyste osseux anévrysmal et 1 cas de fibrome non ossifiant. Le diagnostic différentiel paraît être possible dans une certaine mesure. Le fibrome non ossifiant est peu vascularisé. Les véritables tumeurs à cellules géantes sont hypervascularisées ainsi que certains des kystes osseux anévrysmaux, rendant le diagnostic différentiel impossible dans ces cas. D'autre part, une tumeur peu vascularisée sans composante de tissu

mou et sans fistule artérioveineuse est probablement un kyste osseux anevrysmal Une composante de tissu mou hypervasculaire a une grande valeur pronostique dans les cas de véritable tumeur à cellules géantes

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Book review

MAMMOGRAPHY By W Hoeffken and M Lanyi 341 pages 516 illustrations (32 in colour) Georg Thieme Verlag Stuttgart 1977 Price DM 135

The potential buyer/reader of a medical textbook is presumably interested in obtaining a survey of an unfamiliar field or in extending the boundaries of professional activity by taking up new procedures

As textbooks are written by specialists so are reviews of text books most of the time However while reassuring the reader that major factual faults will be observed this by no means warrants a book as a suitable source of knowledge in other respects Indeed the educated opinion of a fellow student may prove advantageous over that of a specialist in this special kind of consumers information Thus evaluating the merits of this volume against currently available textbooks has prompted the following comments by a neophyte

The book constitutes the first American edition of the German original edition of 1973 translated by Rigler Arndt and Spiegler The main difference from the German edition is the addition of some xeroradiographic illustrations and a general updating The various technical and biologic aspects of mammary diagnosis are fully and systematically covered with a consistent emphasis on correlating radiologic characteristics with those of clinical state surgery and histologic or cytologic classification Low dose film screen combinations in current use are mentioned only in a foot note this is not surprising as recent technical development is no textbook issue

Differential diagnostic considerations are alloted a generous space and are discussed in great detail A separate section is devoted to early detection of breast carcinoma

The utility of any textbook/atlas on radiologic diagnosis is basically dependent on the quality of reproduction of the original roentgen films In this respect the present volume like the German edition comes up to a high standard probably inferior only to that of transparent film copies

Translation inadvertences and printing errors are not quite absent—they constitute some of the few flaws of this book but never create real difficulties

The translation of the German title Rontgenuntersuchung der Brust to the American title Mammography raises a point of terminologic consequence There is a formal international consensus that radiologic examination of an organ by means of a contrast medium should be termed by the combination of the Latin or Greek name of the organ with the suffix graphy as in ventriculography pyelography etc This has been codified in Germany (Dokumentationsschlussel fur Rontgendiagnostik der Deutschen Rontgengesellschaft) as also in the U S by the American College of Radiology (Codes for automatic reporting using computer systems) The use of the term mammography for soft tissue radiography of the breast thus contradicts code as well as logic and should be rejected although it is wide spread A term such as mammary radiography is correct and should be preferred

The authors state that mammary radiography can no longer be the monopoly of a few specialists but should be an established procedure in general radiology With the present volume they have provided an important means of integration which is an excellent entry to the field of diagnosis of diseases of the breast

Ulf Bergvall

FROM THE DEPARTMENT B OF MEDICINE (DIRECTOR O STORSTEIN) AND THE DEPARTMENT OF RADIOLOGY (DIRECTOR T AAKHUS) RIKSHOSPITALET OSLO NORWAY

THROMBOEMBOLIC COMPLICATIONS IN CORONARY ANGIOGRAPHY

Prevention with acetyl-salicylic acid

O STORSTEIN S NITTER HAUGE and I ENGE

Coronary angiography is sometimes followed by complications which may be fatal The incidence varies from 0 1 to 2 6 per cent (BOURASSA & NOBLE 1976 GREEN et coll 1972 GUSS et coll 1975 SHAH et coll 1975 DE LA TORRE et coll 1973) Some of the complications may be related to manipulation of the catheter or reactions to the contrast medium but the most serious ones are primarily those of thromboembolic origin In 46 904 coronary angiographies performed in the United States during 1970 and 1971 (ADAMS et coll 1973) the mortality rate was 0 45 per cent and 6 times higher when the femoral route (0 78 %) was used than with the brachial approach (0 13 %) Myocardial infarction occurred in 0 61 per cent (1 [illegible] % femoral 0 22 % brachial) and cerebral emboli in 0 23 per cent (1 01 % femoral 0 22 % brachial) In a joint investigation from 18 American hospitals during the years 1968 to 1972 66 deaths occurred in 3 044 coronary angiographies—an incidence of 2 1 per cent (TAKARO et coll 1973) Most of these deaths were due to acute coronary artery occlusion other to acute arrhythmias (ventricular fibrillation) and cerebral vascular accidents At autopsy a fresh thrombus was found in 26 of 36 cases with acute occlusion of a coronary artery and in 15 of these a catheter embolus was identified

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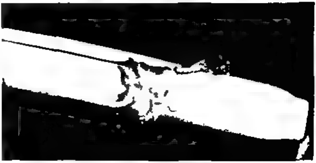

Thrombus on a left ventricular catheter observed during change of the catheter

A fresh thrombus found on a left ventricular catheter of Becton & Dickinson type on changing of the catheter is demonstrated in the Figure Microscopy of the thrombus demonstrated coiled platelets Fibrin and platelets adhered to the surface of the catheter and the thrombus was adherent to the split of the catheter Platelet thrombi apparently originate on the catheter or the guidewire (McCarty & Glasser 1973) used for the transfemoral approach applied in the Judkins technique The sleeve of platelets deposited on the outside of the catheter is wiped off and accumulates at the site of puncture as the catheter is withdrawn (Nejad et coll 1968 McCarty & Glasser) This platelet material may be swept into a coronary artery when the catheter tip nears one of the orifices

Various measures have been recommended to avoid these catheter emboli Coronary artery catheterization should only be performed by experienced radiologists to avoid unnecessary lengthening of the procedure The catheter should be repeatedly flushed by heparinized saline Pressure should be intermittently recorded through the catheter to ensure free position in the vessel Some have recommended heparinization of the patient to avoid thromboembolism (Eyer 1973 Guss et coll 1975 Judkins & Gander 1974) However heparin does not prevent platelet aggregation and platelet deposition on the catheter surfaces General heparinization may be dangerous if the vessel wall is injured Furthermore administration of protamine to abolish the heparin effect at the end of the procedure may be hazardous in patients with severe coronary heart disease Instead it does seem logical to use agents which would retard platelet aggregation on foreign surfaces Acetyl salicylic acid has proved to be effective in preventing thromboembolism in patients with Starr Edward aortic ball valves (Dale et coll 1977) This initiated a comparison between the frequency of thromboembolic complications in two series of patients one without and one with acetyl salicylic acid given as a pre medication before coronary angiography and the results are now reported

Material and Methods

The indication for coronary angiography was evaluation of patients with coronary heart disease for aorto-coronary bypass surgery and of patients with valvular heart disease mostly aortic stenosis with angina pectoris Clinical examination including

routine ECG a graded ECG exercise test on a bicycle ergometer and conventional radiography were carried out before the angiography

The first period (1972–1973) included 852 coronary angiographies the second period (1974–1975) 1 338 In the first period no specific anti thromboembolic prophylaxis was administered During the second period acetyl salicylic acid was given as a premedication 1 g twice on the day before catheterization

The same physicians performed the examinations and the Judkins technique was used in all cases For left ventricular angiography and aortography a single dose of 45 ml of Isopaque Coronar was injected through a Formocath catheter provided with a small end hole and two 1 5 cm long side splits near the tip or a pig tail catheter (Ducor Cordis Corporation) with a Medrad automatic injector (Mark II) the rate of injection being 15 ml/s into the left ventricle and 20 ml/s into the aorta For the selective examination preshaped catheters (Ducor Cordis Corporation) were used and injections of 5 to 9 ml contrast medium were performed by hand repeatedly Pressure registration through selective coronary catheters was recorded continuously except during injection

Results

During the first period 4 deaths occurred all due to myocardial infarction 2 patients with inferior and one patient with subendocardial infarction survived as well as 9 patients with cerebral emboli The emboli were usually small with transient symptoms and signs Only in one patient a left sided hemiparesis remained During the second period 4 died in myocardial infarction and 2 with cerebral emboli survived without sequelae Immediate onset of disturbances of neurologic function with a duration of more than half an hour was considered an indication of cerebral embolism Thus the overall mortality rate was 0 37 per cent most deaths due to acute coronary occlusion In all patients who died autopsy revealed extensive coronary atheromatosis with occlusion or severe stenosis of the left main coronary artery or of both left anterior descending and left circumflex branches Most of the patients had ventricular tachycardia or fibrillation during the angiography Some had cardiac arrest some A-V block followed by asystole One patient had ventricular tachycardia during coronary angiography which was converted to sinus rhythm by DC shock He died 6 weeks later following mitral valve replacement of mitral insufficiency caused by coronary heart disease In one patient emergency aortocoronary venous bypass was carried out but he died during the operation Only in one patient a fresh thrombus was found in the left circumflex branch at autopsy The thrombus measured 6 mm by 2 mm Dissection of the left main coronary artery following the angiography was found in one patient

Discussion

Death following coronary angiography occurred in 0 5 per cent during the first period and in 0 3 per cent during the second most in patients with advanced coronary

heart disease All patients had severe stenosis or occlusion of the left main coronary artery or both of its branches which was in agreement with the finding of BOURASSA & NOBLE (1976) and WOLFSON et coll (1976) The mechanism of myocardial infarction in most instances is supposed to be acute myocardial anoxemia with arrhythmias produced by the stress of the procedure to patients with restricted coronary blood flow In one of the patients the myocardial infarction was produced by dissection of a coronary artery by the catheter In only one instance myocardial infarction was due to coronary emboli presumed to have arisen from a catheter thrombus Measures to prevent catheter thrombosis will therefore probably not be effective in precluding myocardial infarction as most of these are caused by other mechanisms than thrombo embolism

On the other hand the cerebral embolism presumably originates from a thrombus on the coronary catheter or on the guidewire and therefore prevention of platelet aggregation and thus thrombus formation seems to be indicated The use of agents to retard platelet aggregation has been mentioned by ADAMS et coll (1973) and by TAKARO et coll (1973) but no trial with these agents seems to have been reported In the present series the incidence of cerebral embolism was reduced from 1 to 0 15 per cent following administration of acetyl salicylic acid prophylactically

An alternative procedure is heparinization of the patients before angiography as recommended by JUDKINS & GANDER (1974) In the experiments on prevention of clotting on vascular catheters by NEJAD et coll (1968) systemic heparinization was effective to prevent thrombosis WALKER et coll (1973) observed 10 cases of myocardial infarction in 135 non heparinized patients and none in 155 heparinized patients Five cerebral emboli occurred in non heparinized against 2 in heparinized patients Effective prevention of thromboembolic complications by heparin in coronary angio graphy has also been reported by EYER (1973) and GUSS et coll (1975) In experiments in vitro by JACOBSSON & SCHLOSSMAN (1973) and in animals by LAGERGREN et coll (1974) it was demonstrated that heparinized catheters reduced the thrombogenic properties to a remarkable extent The accumulation of platelets on the catheters was less than 10 per cent of that on untreated catheters Recently ELDH & JACOBSSON (1974) have shown that the use of catheters with heparin-coated surface has dramatically reduced the incidence of thromboembolic complications

BOURASSA et coll (1976) have paid attention to the irregular surface of the catheter which is revealed at scanning electron microscopy especially on poly urethane catheters They therefore emphasized the need of high quality catheter material to avoid thromboembolic complications

The present results indicate that the use of acetyl salicylic acid is a valuable alter native in the prevention of thromboembolic complications in coronary angiography Acetyl salicylic acid reduces platelet aggregation and thus retards or prevents platelet thrombus formation It is also suggested to use acetyl salicylic acid in the form of a preparation which is not dissolved in the stomach and thus not producing gastro-intestinal bleeding

SUMMARY

The effect of acetyl salicylic acid to prevent thromboembolic complications in coronary angiography is reported No significant difference in fatality rate between the period without and the period with acetyl salicylic acid was found but significantly less cerebral emboli when acetyl salicylic acid was given prophylactically

ZUSAMMENFASSUNG

Der Effekt von Acetyl Salizylsaure um thromboembolische Komplikationen bei der Koronarangiographie zu verhindern wird beschrieben Keine signifikante Differenz wurde in der Todesfrequenz wahrend der Periode ohne und der mit Acetyl Salizylsaure gefunden aber signifikant weniger Gehirnembolien wahrend der Periode mit Acetyl Salizylsaure

RÉSUME

Les auteurs présentent l effet de l acide acétyl salicylique pour prevenir les complications thrombo-emboliques en angiographie coronaire Ils n ont pas trouvé de différence significative dans le taux de mortalité entre la periode sans et la période avec acide acétyl salicylique mais ils ont constaté un nombre significativement moindre d embolies cerebrales quand on administre de l acide acetyl salicylique préventivement

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FROM THE DEPARTMENT OF THORACIC RADIOLOGY (DIRECTOR G TÖRNELL) KAROLINSKA SJUKHUSET S 104 01 STOCKHOLM SWEDEN

CINEANGIOGRAPHIC DIAGNOSIS OF PAPILLARY MUSCLE INVOLVEMENT IN RHEUMATIC MITRAL STENOSIS

ALFRED SZAMOSI

The essential features of valvular mitral stenosis appearing at left ventricular angiography—whether on full size or cine film—are well established (KJELLBERG et coll 1961 BJORK & LODIN 1960 LIPCHIK et coll 1966 BITTAR & SOSA 1972)

Traditionally the mobility of the cusps the presence or absence of calcific deposits and the competence of the valve have been considered as the main radiologic factors in influencing the feasibility of valvulotomy EIE et coll (1972) have pointed out the possiblity of the preoperative diagnosis of the funnel type of mitral stenosis by means of cineangiography The diagnosis seems to have been based on the shape of the orifice and the type of movement of the anterior mitral cusp The possibility of direct demonstration by cineangiography of the fusion between the papillary muscles and mitral valve a common sequela of rheumatic endocarditis will now be reported

Material

The radiologic features of papillary muscle involvement were analysed in 46 patients who underwent preoperative cardioangiography at this department and were subsequently operated upon for rheumatic mitral valve disease at the Department

Based on a lecture held at the 34th Congress of the Scandinavian Society of Medical Radiology Århus Denmark 1975 Submitted for publication 22 July 1976

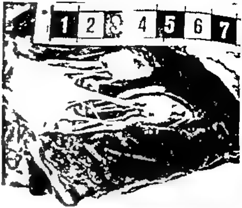


Fig 1 The interior of the left ventricle as seen from the interventricular septum which is removed This plane of section will give an appearance to the left ventricular cavity resembling that seen in the right anterior oblique projection in cine angiography The spatial relation between the papillary muscle tips and mitral leaflet margins is commonly found in patients without mitral valve disease

of Thoracic Surgery at this hospital Three additional patients with the cardioangiography performed at another hospital were included To establish the angiographic features of normal relations between mitral leafl ts and papillary muscl·s the left ventricular cineangiograms of 25 patients without evidence of mitral valve disease were reviewed This control group included 21 patients with ischaemic heart disease and 4 with pure valvular aortic stenosis Care was taken not to include in the control group patients with heart enlargement pathologic movements of the l·ft ventricular wall increased end-diastolic left ventricular volume or where mitral valve dis ase could not be excluded

Methods

The examination was performed in a similar way in the mitral stenosis and control groups For cineangiography 50 to 60 ml of Urografin 60 % were injected into the left ventricular cavity at a rate of 14 to 18 ml/s in the majority of the cas·s In 3 instances the same amount of Urografin 76 % was injected into the main pulmonary artery at a rate of 25 to 30 ml/s and the passage of the contrast medium through the l·ft heart was then recorded The recording was made on 35 mm cine film at a rate of 42 frames s utilising a Philips bi plane equipment with caesium iodide activated image intensifiers (23 cm 9) Two subsequent injections were performed in all cases yielding a total of four projections p a lateral right ant·rior oblique and left anterior oblique respectively At the preoperative analysis of the films particular attention was paid to the question whether the papillary muscles or one of them were coalesced with the leaflet margin or whether the distance between the two structures (i e papillary muscle tip and leaflet margin) was markedly reduced or not To this end the cine films were projected slowly moving back and forth during s·veral consecutive heart beats to find the phase of optimum delineation for the papillary muscles At subsequent operation whenever possible the mitral leaflets were excised en bloc with the papillary muscle tips attached In these cases a direct comparison of the preparation with the film could be made In the remaining cases where open

Fig 2 Left ventricular cineangiography Mid systole No clinical physiologic or radiologic evidence of mitral valve disease (patient with coronary artery disease normal movements of the left ventricular wall) The interspace between the papillary muscle heads and the margins of the closed mitral valve is filled with contrast medium

comissurotomy or transventricular dilatation was performed or where the mitral valve had to be removed in small pieces the comparison was made between the preoperative diagnosis and the finding of the surgeon at operation

Results

In the group without mitral valve disease a contrast filled interspace could be observed between the margin of the closed mitral valve and the tip of the papillary muscles in every instance whenever these structures could be observed at all Mostly this occurred only on a few frames at mid systole when the mitral leaflets were in apposition and the papillary muscles bulged maximally into the left ventricular cavity which however was not yet emptied of contrast medium (Fig 2) This inter space appeared to be widest in the right anterior oblique projection in the other projections it was more narrow or could not be observed at all (Fig 7)

In the mitral valve disease group virtual coalescence of one or several papillary muscle tips with the leaflet tissue was observed in the right anterior oblique projection in 24 cases (Fig 4) This finding was confirmed at operation in all cases except one in that partial or complete fusion between papillary muscles and leaflets or at least severe shortening of the chordae was present (Fig 3)

In 5 cases the interspace could be observed on the film while gross thickening of the leaflets and their complete fusion with the papillary muscles was found at opera tion The first 3 of these cases were wrongly considered as absence of fusion pre operatively

In 18 cases the relations between mitral leaflets and papillary muscles appeared to be normal on the cineangiogram which was confirmed at operation

In one case (Fig 5) the tip of the antero lateral papillary muscle seemed to protrude up to the leaflet margin On the basis of the obvious tapering of the papillary muscle head and its point like attachment instead of the broad irregular contact area

Fig. 3 En bloc excised parts of the mitral valve from a patient with severe rheumatic mitral stenosis The chordae are thickened shortened and partly coalesced Almost complete fusion between the postero-medial papillary muscle and the mitral valve around the medial commissure

in pathologic cases (Fig 4) the appearance was considered as an anatomic variation (RUSTED et coll 1952) not fusion

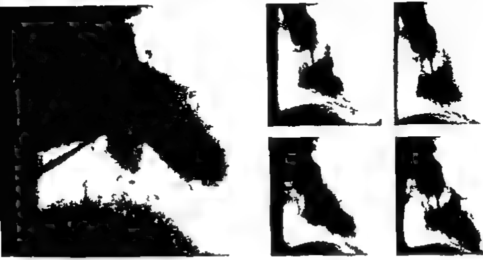
In 5 cases large irregular masses involving at least one papillary muscle and extending into the leaflets were observed in the right anterior oblique and lateral views (Fig 6) At operation complete coalescence between the papillary muscle and leaflets was found with gross irregular thickening of the tissue At the involved commissure the posterior cusp and papillary muscle were adherent to the ventricular wall

Linear well defined contrast defects between the tip of postero medial papillary muscle group and valve leaflets best visible in the lateral projection were a common finding in the mitral stenosis group and were initially considered as thickened chordae (LIPCHIK et coll 1966 EIE et coll 1972) While in a few cases the similarity of the angiographic appearance and the preparation at the operation was striking gross over or underestimation of the thickness of the chordae was frequently made

En bloc excised mitral leaflets with papillary muscle tips attached were obtained and could be compared with the film in 24 instances

Discussion

Complete stiffness of the mitral valve leaflets the presence of large calcific deposits and moderate or severe regurgitation have traditionally been considered as contraindications to attempt valvulotomy in cases of mitral stenosis (GOODWIN et coll 1955) All these features are readily observable at preoperative left ventricular cineangiography and their recognition will as a rule lead to the decision to replace the valve However the rheumatic process may involve the chordae tendini resulting in their fusion thickening and shortening At advanced stages the papillary muscle from which the chordae emanate may virtually coalesce with the leaflets pulling them downwards Also the papillary muscle may become adherent to the adjacent ventricular wall (BROCK 1952 RUSTED et coll 1956) These alterations of the normal



a b

Fig. 4. a) Cineangiography. Mid-diastole. Evident fusion between the dome shaped stenotic mitral valve and the papillary muscles. b) For comparison, the appearance of rheumatic mitral stenosis without fusion between the papillary muscles and the leaflets.

anatomy may have twofold significance. First, they may become a contributing factor to the impediment of flow from the left atrium to ventricle (funnel type stenosis); secondly, their presence may influence the surgical technique (SPENCER 1969, BJÖRK 1974).

Normally, the chordae tendini extend radially from the tip of each papillary muscle to both cusps and are, therefore, of different length. The distance between the papillary muscle tip and cusp margin is usually of the order of 1.5 cm and is believed to be constant throughout the cardiac cycle. On a left ventricular cine angiogram, it is the projection of this distance in the plane of the input screen of the image intensifier that is recorded and appears as an interspace filled with contrast medium separating the two structures. As the papillary muscles are aligned approximately parallel to the longitudinal axis of the left ventricular cavity, the apparent distance (as seen on the film) will be a trigonometric function of the spatial orientation of the left ventricle with respect to the central beam. It is fair to assume, then, that the least geometric foreshortening will be obtained in the right anterior oblique projection, where the left ventricular cavity usually stands nearest to parallel to the input screen of the image intensifier. In the a.p. and lateral projections anatomic foreshortening of the chordae will appear aggravated.

The persistence or disappearance of the interspace between the papillary muscles and mitral leaflets may, therefore, be best appreciated in the right anterior oblique projection. The width of this interspace has not been measured in the present material. The interspace itself was, however, invariably demonstrated in the right anterior oblique projection, whenever the two structures were outlined at angiography

a b

Fig. 5 a) Excised parts of mitral valve with rheumatic disease The chordae are thickened but not coalesced The tapering head of the lateral papillary muscle practically in contact with the lateral commissure is probably representing an anatomic variation not a pathologic fusion b) Left ventricular cineangiography The anatomic situation is correctly demonstrated ( ) (the postero-medial papillary muscles were delineated in an other sequence not shown here)

and no fusion was present whether in the mitral valve disease or in the control group As a rule the separation between the papillary muscle and the leaflet is observed—in spite of geometric foreshortening even in the a p projection (Fig 7) and to a lesser extent in the lateral projection

The false impression of a free interspace between the leaflets and papillary muscle tip has arisen in a few cases The reason appeared to be the confusion of the sharply outlined dome shaped curved surface of the basal i e non marginal part of the stenosed valve with the true margin of the markedly thickened completely immobile leaflets aligned in a plane approximately parallel to the input screen of the image intensifier These changes could readily be observed in the lateral or left anterior oblique view and the mistake could be avoided once its source had been recognised

Correct delineation of the papillary muscles may sometimes present difficulties Three factors contributing to these difficulties should be mentioned First large amount or high concentration of contrast medium causing suboptimum penetration of the films obviously restricts the possibilities of recognising details Secondly complete mixing of contrast medium with blood already present in the left ventricle or the phasic inflow of blood from the left atrium may generate confusing contrast defects Thirdly variations in the features of the papillary muscles including size shape number of heads and mode of attachment to the ventricular wall are common (RUSTED et coll 1952 ROBERTS & COHEN 1972) The use of Urografin 60 % (290 mg I ml) instead of 76 % (370 mg I/ml) was felt to facilitate the recognition of details within the left ventricle The volume of contrast medium (50 to 60 ml) allowed a duration of the injection of about 3 seconds or more The constant reappearance of

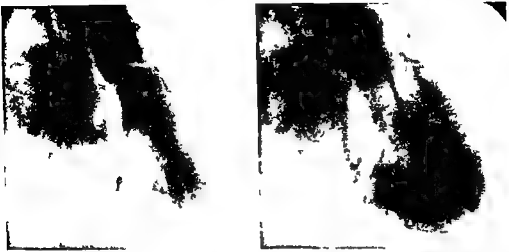


Fig 6

Fig 6 Left ventricular cineangiography Large contrast defect involving papillary muscles part of the leaflets and posterior ventricular wall representing coalescence of these structures in one large inflammatory mass This was confirmed at operation where the valve could only be removed in small portions

Fig 7 Normal spatial relations between leaflet margins and papillary muscle tips as seen in the a p view in a patient with mitral stenosis No appreciable shortening of the chordae was found at operation The interspace between mitral leaflets and papillary muscles is evident but appears foreshortened

the findings during this time interval covering several heart beats may be assumed to *diminish the risk of confusion flow artefacts with real pathologic structures*

Fusion of several chordae radiating from the same papillary muscle is probably indistinguishable from fusion between the papillary muscle and leaflet margin but this phenomenon did not occur in the present series

The preoperative recognition of papillary muscle involvement in rheumatic mitral stenosis appears to be of clinical importance When present it will render valvulotomy more difficult and hazardous Therefore it seems to be advisable to make preparations for valve replacement when operation is planned in such cases

SUMMARY

Left ventricular cineangiography was performed in 25 patients with normal mitral valves and in 49 patients with rheumatic mitral valve disease to estimate the spatial relations between the mitral valve leaflets and papillary muscles The findings in the pathologic group were compared with observations at operation or with the excised mitral valves It is concluded that fusion of the papillary muscles with the mitral valve leaflet or severe shortening of the chordae is predicted with a reasonable accuracy preoperatively by means of left ventricular cineangiography The surgical implications are discussed

ZUSAMMENFASSUNG

Kineangiographie des linken Ventrikels wurde bei 25 Patienten mit normalen Mitralisklappen und bei 49 Patienten mit rheumatischen Erkrankungen der Mitralisklappe vorgenommen um raumliche Verhaltnisse zwischen den *Segelklappen* des Mitralisostiums und der Papillarmuskel festzustellen Die Befunde der pathologischen Gruppe wurden mit Beobachtungen bei der Operation oder mit den entfernten Mitralisklappen verglichen Daraus wird geschlossen dass die Fusion der Papillarmuskeln mit den Segelklappen oder eine schwere Verkurzung der Chordae mit genugender Genauigkeit praoperativ durch die Kineangiographie des linken Ventrikels beurteilt werden kann Die Folgerungen fur die Operation werden diskutiert

RESUMÉ

Une cinéangiographie du ventricule gauche a eté faite chez 25 sujets ayant des valvules mitrales normales et chez 49 malades ayant une lesion rhumatismale de la valvule mitrale pour etudier les relations spatiales entre les valves mitrales et les muscles papillaires Les resultats obtenus dans le groupe pathologique ont eté compares avec les constatations opératoires ou avec les valves mitrales réséquees L auteur conclut que la fusion des muscles papillaires avec les valves mitrales ou le raccourcissement grave des cordages tendineux peut être prevu avec une précision raisonnable avant l opération grâce à la cinéangiographie du ventricule gauche L auteur discute les conséquences chirurgicales de ces resultats

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Tomography Physical Principles and Clinical Applications By J T Littleton Section 17 of Golden s Diagnostic Radiology Williams and Wilkins Baltimore 1976 Price $36

Most radiologic clinics have a tomograph However many of these are underutilized because many radiologists have rather dim knowledge about how to use the machine and what to gain from it Learning tomography implies learning to understand the geometrically complex process of how the continually changing radiographic projection affects blurring as well as depiction of structures within or near the tomographic plane One of the most prominent contemporary advocates of tomography in the USA has assumed the difficult task of writing a textbook for the general radiologist having no special knowledge of tomographic theory On the whole the attempt has been successful

The book gives a complete survey of problems associated with tomography Actually it may be considered too complete since the thickness of the book (some 800 pages) may discourage hard working doctors with but limited time for continued education from giving it its proper share of attention This would be a pity since the book is written in a way that makes it directly useful in daily clinical routine work The chapter Technical Aspects gives comprehensive instructions as to the proper tomographic procedure for different organs and projections The rushed doctor can start by using this chapter as a practical manual This will lead him on to the chapters dealing with normal tomographic anatomy and pathologic changes when the films are to be evaluated Later he may read the more difficult theoretical chapters—in fact he should in order to get the most out of his tomograph

The book is richly illustrated with high quality tomograms printed with great care

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ANGIOGRAPHY OF THE REGENERATING LIVER AFTER LOBAR RESECTION

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Resection of liver tumors primary or secondary is at present the only chance for permanent cure Resection of large parts of the liver is possible since the remaining liver parenchyma regenerates rapidly However it is technically possible to remove only those tumors confined mainly to one lobe (ALMERSJÖ et coll 1976)

Few reports exist on the angiographic appearance of liver regeneration (BENGMARK et coll 1969 ARONSEN et coll 1970 ENGE & FLATVIK 1972) The present investigation was performed to follow the angiographic appearance of the regenerative process after tumor resection in an attempt to detect possible tumor recurrence

Material

The series consisted of 18 patients 12 women and [illegible] men aged 26 to 73 years 14 were between 48 and 64 years Primary liver tumor was evident in 8 patients 3 with hepatocellular carcinoma and 5 with cholangiocarcinoma Metastatic disease of the liver was the cause of resection in 8 patients the primary tumor being colonic carcinoma in 4 small intestinal carcinoid carcinoma of the ovary leiomyosarcoma of the uterus and unknown in one patient each Liver resection was performed in [illegible] patients because of echinococceal cysts Resection of the right lobe was

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Table

Time lapse in months between liver resection and postoperative angiography in 18 patients

Months	No of patients		
	First angiogr	Second angiogr	Third angiogr
<2	4		
2–4	5		
4–6	5		
6–12	1	4	
12–18	3		
18–24		2	2
24–30			2
Total	18	6	4

performed in 13 patients In 2 of these the resection was segmental only while in 4 cases the resection was extended also to the medial segment of the liver lobe Resection of the left liver lobe was performed in 5 patients in 2 of whom only the lateral segments were removed

Methods

Preoperative angiography of the celiac and superior mesenteric arteries and usually also of the hepatic artery was carried out in all patients The angiography was performed within 2 months before the operation in 17 patients and 5 months preoperatively in one patient with echinococceal cyst One postoperative angiography was carried out in all patients 2 in 6 and 3 in 4 patients Details concerning the time lapse between the operation and the postoperative angiography are given in the Table

At preoperative angiography the size of the part of the liver without tumor involvement was evaluated mainly from the anatomy of segmental arteries but also from the extension of the accumulation of the contrast medium within the parenchyma At the postoperative angiography the size of the remaining liver parts was evaluated by the same criteria Moreover evidence of tumor recurrence which could influence the process of regeneration was looked for as was the presence of collaterals to the area of resection Any change in width of the hepatic artery and its branches was also noted

Results

Right lobe resection The group consisted of 13 patients of whom 10 had enlargement of the left liver lobe preoperatively The enlargement was marked in 5 of these

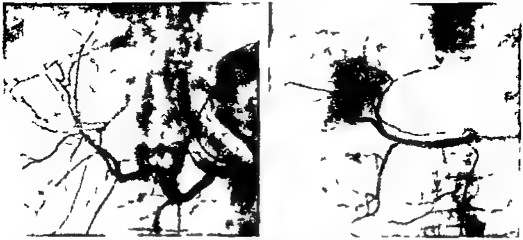
Fig 1 Female aged 43 with echinococceal cyst in the right liver lobe a) Hepatic artery injection Stretching and displacement of intrahepatic arterial branches and some uptake of contrast medium in the cyst walls Arteries to lateral segments of left lobe are separated indicating enlargement of left lobe b) 3 years after resection of dorsocaudal segment and parts of ventrocranial segments of right lobe Arterial branches to medial segment of left lobe stretched indicating hyperplasia Right hepatic artery ligated Filling of peripheral branch to ventrocranial segment of right lobe via intrahepatic collaterals (↔) Right phrenic artery wide giving collaterals to hypervascular resectional area (→)

cases (Figs 1 2 3) Regenerative hyperplasia was demonstrated postoperatively in all the patients also in those in whom segmental resection only had been performed The degree of enlargement correlated well with the preoperative size of the left lobe i e the degree of hyperplasia was less marked when the left lobe was large pre operatively whereas the most marked increase in size was registered among those patients who had a small left lobe preoperatively

The angiographic appearance of the hyperplasia was characteristic with rotation and stretching of the segmental arteries while the regenerating liver parts rotated to fill the empty space in the right hypochondrium (Figs 2 3 4) In 2 patients only did this space remain empty

Pre and postoperative determination of the width of the left hepatic artery was possible in 9 patients Increase in diameter was evident in 2 patients and decrease in 4 The intrahepatic arterial branches were in all cases narrower postoperatively

The process of regeneration was rapid being complete at the first postoperative examination i e in 9 patients within 4 months In one patient it was already evident 6 weeks postoperatively In one patient only did additional enlargement occur between examinations made 2 5 and 10 months postoperatively This latter patient also displayed a localized regenerative nodule resembling focal nodular hyperplasia



a b

Fig 2 Female aged 58 with malignant hepatoma of right liver lobe a) Hypervascular tumor in right lobe enlarged left lobe displaced to the left b) 2 5 months after right lobe resection Left lobe fills the space in the right hypochondrium All arterial branches to lateral segments separated from each other and stretched due to regeneration

(Figs 2 3) Regenerative enlargement was in no case noted at examinations performed later than 13 months postoperatively

Tumor recurrence was demonstrated by tumor vessels and uptake of contrast medium within the tumor in 3 patients In an additional 3 patients some tortuous arteries were demonstrated in the area of resection These arteries were more regular than tumor vessels (Concomitant uptake of contrast medium was never seen) These vessels were considered to be collaterals from the liver parenchyma to the granulating resection area Intrahepatic collaterals were demonstrated in one patient in whom only segmental resection of the right lobe was performed (Fig 1) Extrahepatic collaterals to this same area from the inferior phrenic artery were demonstrated in 6 patients and from other small retroperitoneal vessels in an additional patient (Figs 2 3)

Left lobe resection This group comprised 5 patients The right lobe was evaluated as being of normal size in all the patients preoperatively In 4 of the patients some degree of hyperplasia was evident postoperatively The hyperplasia was demonstrated as early as 6 weeks postoperatively in one patient In another patient the enlargement of the right lobe continued and had increased also between the first and second post operative angiography after 16 and 22 months respectively (Fig 5) In only one patient was regenerative hyperplasia not demonstrated Tumor recurrence was evident in one patient It was possible to measure the width of the right hepatic artery in all the patients pre- and post-operatively An increase was evident in one patient and a decrease in 4 The width of the intrahepatic arterial branches was unchanged in all the patients however some stretching and loss of tortuosity indicated the hyper

a b

c

Fig 3 Same case as Fig. 2. a) 10 months postoperatively More marked stretching of segmental branches which are narrower than before Also hepatic artery narrower b) Late parenchymal phase at same examination Intense uptake in a regenerative nodule c) 2 years and 3 months postoperatively No further regenerative hypertrophy as indicated by arterial displacement. Right phrenic artery dilated and gives tortuous collaterals to area of resection

plasia A prominent finding was deformation of the extrahepatic course of the hepatic artery (Fig 5) Tortuous arteries in the area of resection were evident in one patient (Fig 6c) Extrahepatic collaterals were not demonstrated

Discussion

The liver in man has an extremely high potency for regeneration even if the rate of the process is not as high as in the rat (BENGMARK 1968 a b) The stimulus to regenerative hyperplasia of the remaining liver parts is found to be greater the smaller the remaining part (PACK et coll 1962) This corresponds well to the present findings the most marked enlargement being noted after extended resection of the right liver lobe However it should be emphasized that some degree of hyperplasia was evident also after small resections as in 2 of the patients in whom only part of the right liver lobe was removed Slight enlargement of the right lobe and medial segment of the left lobe was also noted in one patient in whom only the lateral segments of the left lobe were resected

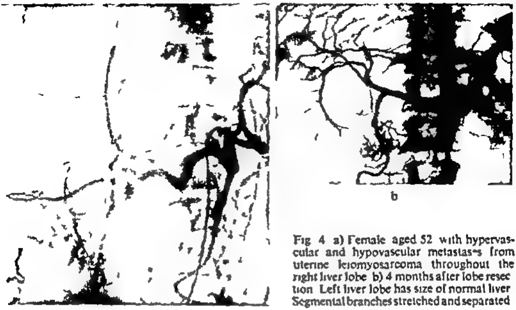


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Fig. 4. a) Female aged 52 with hypervascular and hypovascular metastases from uterine leiomyosarcoma throughout the right liver lobe. b) 4 months after lobe resection. Left liver lobe has size of normal liver. Segmental branches stretched and separated.

The angiographic appearance of left lobe regeneration was always characteristic. The segmental arteries were stretched and separated from each other and in addition rotated (Figs 2, 3, 4). The regenerating liver filled the empty space under the right diaphragm in all but 2 of the patients in whom the right lobe was resected (Fig. 4). The total size of the regenerated liver may be the same as that of a normal liver but has a rounder contour, the sharp edge of the right lobe normally pointing to the right iliac fossa is absent. Similar findings are reported by BLUMGART et coll. (1971) at scintigraphy. Hyperplasia of the right lobe after resection of the left lobe was more difficult to appreciate. It was easiest to define in the area of the dorsocaudal lobe where displacement and stretching of arteries was evident (Fig. 5).

The regeneration starts immediately after resection and 3 weeks later the liver function is normal (PACK et coll. 1962). In the present series the regeneration, with few exceptions, was complete at the first postoperative angiography, i.e. in most instances within half a year after operation. A slight additional enlargement of the right liver lobe was evident in one patient between 16 and 22 months postoperatively and in another patient with resection of the right liver lobe between examinations performed 2, 5 and 10 months postoperatively. The part of the normal liver constituting the left lobe probably varies. PACK et coll. state that extended right lobe resection leaves only 20 per cent of the liver mass. On the contrary, BLUMGART et coll. (1971) estimate right lobectomy at 50 per cent of the liver parenchyma. An evaluation of the size of the left lobe based on angiography is difficult, but in the present series the left lobe seemed to be enlarged already preoperatively in 10 of 13 patients with a tumor in the right lobe (Figs 1, 2, 3). This may support the hypothesis that humoral factors may initiate regeneration already preoperatively (WEINBREN 1959).

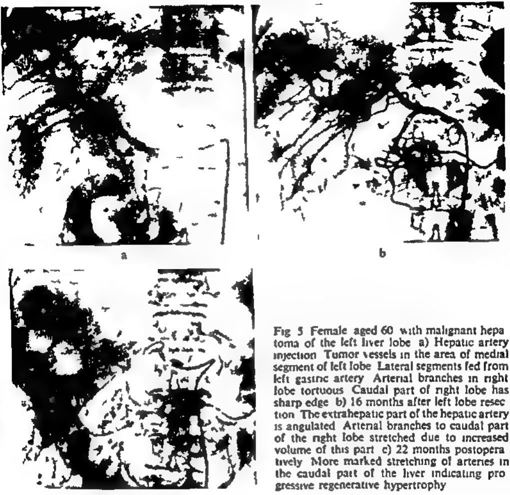

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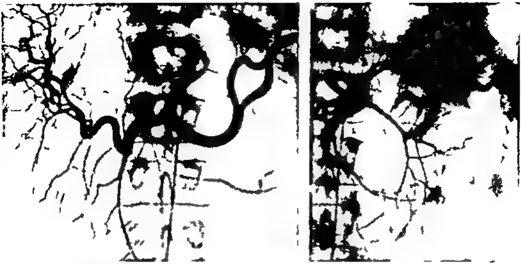
Fig 5 Female aged 60 with malignant hepatoma of the left liver lobe a) Hepatic artery injection Tumor vessels in the area of medial segment of left lobe Lateral segments fed from left gastric artery Arterial branches in right lobe tortuous Caudal part of right lobe has sharp edge b) 16 months after left lobe resection The extrahepatic part of the hepatic artery is angulated Arterial branches to caudal part of the right lobe stretched due to increased volume of this part c) 22 months postoperatively More marked stretching of arteries in the caudal part of the liver indicating progressive regenerative hypertrophy

The hepatic arteries are reported to hypertrophy during liver regeneration (BENGMARK et coll 1969 ENGE & FLATVIK 1972) In the present series the diameter of the left and right hepatic arteries in most patients was found to be reduced compared with the preoperative angiography The cause of this discrepancy is not clear The time lapse between angiography and operation may be of importance in most instances the regeneration was already complete at the time of postoperative angiography The intrahepatic arteries in the regenerating liver were stretched and had lost normal tortuosity due to the marked hyperplasia of the parenchyma (Figs 2 3) as previously reported (ARONSEN et coll 1970 ENGE & FLATVIK) As a rule the width of the intrahepatic arterial branches was reduced compared with the preoperative one

Newly formed vessels were not demonstrated unless tumor recurrence was evident In a few patients some tortuous slightly irregular vessels stemming from intra



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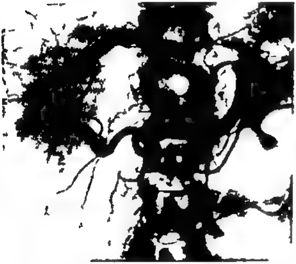

c

Fig [illegible] Man aged 37 with metastasis to the left liver lobe from unknown primary tumor a) Celiac artery and b) left gastric artery injection The metastasis is avascular displacing branches to left lateral segments c) 6 weeks after resection of the entire left lobe Tortuous collaterals (→) in the area of resection

hepatic arteries were demonstrated in the proximity of the resection They looked more like collaterals to the granulating resection surface Other common collaterals to the area of resection were from the right inferior phrenic artery The importance of this artery as a source for collateral pathways to the liver is well known (BENGMARK & ROSENGREN 1970 WIRTANEN & KAUDE 1973) These collaterals were often quite rich giving rise to a network of small vessels in some of the patients initially incorrectly diagnosed as indicating tumor recurrence or subphrenic abscess (Figs 1 2 3) Intrahepatic arteries are often considered to be end arteries although some recent reports have contradicted this opinion (MAYS & WHEELER 1974 PETTERSSON 1975) In one patient with segmental resection of the right lobe but with ligature of

hepatic artery intrahepatic collaterals were demonstrated also indicating possible intrahepatic collaterals (Fig 1)

Another interesting finding is a regenerative nodule in one patient with the appearance of focal nodular hyperplasia (Figs 2 3) This hyperplasia has a characteristic angiographic appearance and is seen particularly in conjunction with oral contraceptives (GOLDSTEIN et coll 1974 ZUBRRIGGEN & TYLÉN 1975) However the focal nodular hyperplasia in this case appeared as part of the regenerating process

SUMMARY

Angiography was performed in 18 patients before and after resection of parts of the liver The regenerative process was as a rule complete within few months and had a characteristic appearance with mainly stretching and displacement of arteries

ZUSAMMENFASSUNG

Angiographie wurde bei 18 Patienten vor und nach Resektion eines Teils der Leber vorgenommen Die regenerativen Prozesse waren im ganzen innerhalb von wenigen Monaten abgeschlossen und hatten ein charakteristisches Bild mit vorwiegend Streckung und Verlagerung der Arterien

RESUME

Les auteurs ont fait une angiographie chez 18 malades avant et apres résection hepatique partielle Le processus de regeneration est en géneral complet en l espace de quelques mois et a un aspect caractéristique consistant principalement en un etirement et un deplacement des artères

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ANGIOGRAPHY IN HEREDITARY HEMORRHAGIC TELANGIECTASIA

ULF NYMAN

Hereditary hemorrhagic telangiectasia or Rendu Osler Weber disease is a vascular disorder characterized by telangiectasia of the skin mucous membranes or internal organs and by hemorrhages that arise from rupture of the telangiectatic lesions A family history is present in approximately 80 per cent of the cases Both sexes seem to be affected with equal frequency (SMITH & BARTHOLEMEW 1963)

The telangiectatic lesion consists of thin walled and dilated vascular channels with arteriovenous communications Coalescent lesions may expand to several centimeters in diameter and act as clinically significant arteriovenous shunts and be the site for thrombo embolism formation (ROBINS 1968 JAHNKE 1970) Arterial aneurysms may be present and have been observed mainly in the abdominal vessels (SCHUSTER 1937 HALPERN *et coll* 1968 BORMAN & SCHILLER 1969)

It is generally held that the disease is the result of congenital defects within the vessel walls and becomes manifest because of hemodynamic factors acting on the vulnerable vessels (SMITH & LINEBACK 1954 STINNER 1966 VON GULZOW et coll 1969)

Visceral telangiectasia may cause gastrointestinal hemorrhages and abdominal pain The liver and spleen may be enlarged Telangiectatic arteriovenous fistulas in the liver may result in pulmonary hypertension and heart failure Pancreatic and splenic fistulas may produce portal hypertension (FOSTER & SANDBLOM 1961)

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Fig 1 Case I 50-year-old woman with pulmonary hypertension probably as the result of arterio-venous fistulas in the liver and repeated episodes of gastrointestinal hemorrhages a) Superior mesenteric & c) celiac angiography a) Dilated and tortuous right hepatic artery normal superior mesenteric artery irregular and dense accumulation of contrast medium in the liver parenchyma b) Dilated and tortuous left hepatic artery and small splenic artery with 4 aneurysms (→) c) Dilated hepatic veins and a few portal venous branches (↔)

Polycythemia cyanosis hippocratism and cerebral symptoms indicate pulmonary lesions as well as spontaneous hemothorax and hemoptysis in patients with telangiectasia Cerebral symptoms may also be caused by cerebral telangiectasia and by portosystemic fistulas as in the case reported by MICHAELI et coll (1968)

In vivo demonstration of telangiectasia of internal organs is dependent upon radiography of the chest angiography and endoscopy The aim of the present report is to draw attention to the significance of angiography in patients with telangiectatic lesions and to illustrate angiographic features in splanchnic and pulmonary manifestation of the disease

Material and Methods Angiography was performed in 5 patients with a family history of hemorrhagic telangiectasia and mucocutaneous lesions pulmonary

Table

Telangiectatic lesions demonstrated on angiography and autopsy

	Case				
	1	2	3	4	5
Brain	–	0	0	+	0
Lungs	–	–	+	+	+
Liver	+	+	+	+	0
Pancreas	–	+	–	–	0
Spleen	–	+	–	–	0
Intestine	–	+	–	–	0
Aneurysms	+	–	+	–	0

– Not observed
0 Not examined

angiography was performed in all 5 patients and celiac and mesenteric angiography in 3. A complementary examination of the aortocervical region was made in one patient. Two patients died from causes related to the disease and autopsies were performed (Cases 1, 4).

Results

The organs which at angiography and autopsy were found to be involved appear in the Table. Hepatic telangiectasia was observed in all 3 cases examined at angiography and in one patient at autopsy. The hepatic arteries were dilated and tortuous. Numerous irregular contrast pools were scattered throughout the liver parenchyma (Figs 1 a, b, 4 a, 5 b). Rapid filling of hepatic veins was obvious in two patients and in one of them filling of a few portal venous branches was present as well (Fig. 1 c). The third patient exhibited numerous intrahepatic arterioportal communications (Fig. 4 b). In one patient multiple rather well defined arteriovenous malformations were present in the pancreas with shunting of the contrast medium to the splenic vein (Fig. 4 c). In the same patient one small arteriovenous fistula in the spleen and one in the distal ileum were demonstrated (Fig. 4 c, d).

Arterial aneurysms were found in two patients (Figs 1 b, 2).

Pulmonary lesions found in 3 patients appeared as single or multiple arteriovenous fistulas (Fig. 5 a) and as multiple communications between dilated vessels in a localized area (Fig. 6). The lesions were apparent on chest films. Pulmonary angiography in Case 1 revealed signs of pulmonary hypertension but no fistula formation.

At autopsy telangiectasia in the liver and brain was found in Case 4, and in Case 1 only the liver was involved. The liver in Case 1 was enlarged and multinodular. The nodules varied in diameter from a few millimeters to 2 centimeters and showed umbilication. Corrosion cast of the right hepatic artery illustrated the wide and

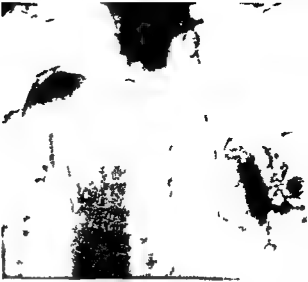

Fig. 2. Right aortic arch, left aortic diverticulum and aneurysmatically dilated bronchial arteries. No connection between bronchial arteries and pulmonary arteries.

tortuous hepatic arteries with peripherial arteries branching off into numerous vessel tufts (Fig. 3). Via those tufts hepatohepatic and a few hepatoportal communications could be demonstrated. Corrosion cast of the portal vein was regarded normal.

Discussion

The angiographic findings of hepatic telangiectasia in the present cases are in agreement with previous reports on this subject (RANNIGER & ÖDMAN 1963, HALPERN et coll. 1968, MENANTEAU 1969, ANDRÉ et coll. 1971, BACARDI et coll. 1971, THOMAS & CARTY 1974). It must be emphasized that the angiographic appearance is dependent on the stage of development of the telangiectatic lesion. In severe cases the common hepatic artery may reach the size of the abdominal aorta. The hepatic veins are, as a rule, not observed during hepatic angiography but when observed should call attention to arteriovenous malformations. The degree of shunting may vary from only a few peripheral contrast filled veins to complete demonstration of the hepatic veins. The corrosion cast of hepatic arteries illustrates the vascular malformation, which corresponds well to the contrast pools in the angiogram. However, the telangiectatic lesions may be small and diffusely scattered in the liver that they cannot be demonstrated as pools at angiography. Hepatic telangiectasia in such a case can be anticipated if there is early filling of hepatic veins. However, filling of hepatic veins during hepatic angiography may appear in other conditions as well. Thus, it has been found in patients with reduced portal blood flow, infantile hemangiomas, richly vascularized metastatic neoplasms and, rarely, during normal conditions (GLICKMAN & HANDEL 1972).

Intrahepatic arterioportal communications, observed in 2 of the patients, have been reported in a variety of disorders in the liver (ITZCHAK et coll. 1974). Most

Fig 3 Case 1 Corrosion cast of right hepatic artery demonstrating peripheral arteries branching off into the vessel tufts

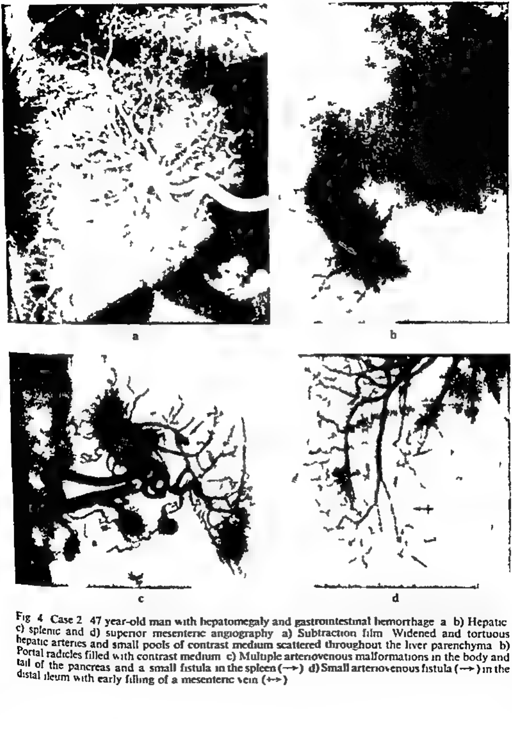

Fig 4 Case 2 47 year-old man with hepatomegaly and gastrointestinal hemorrhage a b) Hepatic c) splenic and d) superior mesenteric angiography a) Subtraction film Widened and tortuous hepatic arteries and small pools of contrast medium scattered throughout the liver parenchyma b) Portal radicles filled with contrast medium c) Multiple arteriovenous malformations in the body and tail of the pancreas and a small fistula in the spleen (→) d) Small arteriovenous fistula (→) in the distal ileum with early filling of a mesenteric vein (↔)

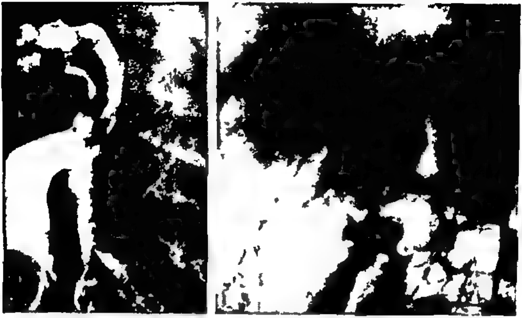

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Fig 5 Case 3 59 year-old woman treated for pulmonary tuberculosis 15 years previously Mild recurrent gastrointestinal hemorrhages had been present for several years Radiographic control of the pulmonary condition revealed an arteriovenous fistula in the apex of the left lung a) Pulmonary and b) celiac angiography a) Subtraction film Dilated pulmonary artery and 2 draining veins connected by an aneurysmal sac b) Dilated and tortuous hepatic arteries and irregular accumulation of contrast medium in the liver parenchyma The hepatic veins filled as in Case 1

often it is observed in cirrhosis and portal hypertension Hepatic telangiectasia per se may constitute a form of liver cirrhosis according to some authors (ZELMAN & TOPEKA 1962 FEIZI 1972) Other forms of cirrhosis such as nutritional cardiac and postnecrotic and hepatocellular carcinoma have been reported in patients with hereditary telangiectasia (SUSSMAN & STERNBERG 1975) The arterioportal communications in the present series could therefore be secondary to cirrhosis although in Case 1 there was no evidence of true cirrhosis at autopsy and in Case 2 no abnormality indicating portal hypertension It may be assumed that these communications probably were of telangiectatic origin

A few cases of telangiectatic lesions of the pancreas have been reported but only twice been demonstrated by angiography Hence HALPERN et coll (1968) reported a case with dense accumulation of contrast medium within the body and tail of the pancreas and early filling of the portal system indicating diffuse telangiectatic involvement REUTER & REDMAN (1972) presented a case in many respects similar to the present one

Other hypervascular lesions with arteriovenous shunting may be observed in the

Fig 6 Case 5 (granddaughter of Case 4) 7 year-old girl with congenital polycythemia Pulmonary angiography Wide spread arteriovenous malformation in the upper lobe of the right lung with simultaneous contrast filling of the left side of the heart

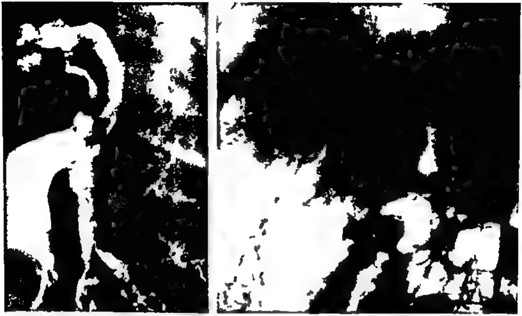
pancreas but they do not have a similar small rather well circumscribed appearance of pancreatic telangiectasia Thus angiosarcoma malignant angiomatous tumor hemangioma and pancreatic arteriovenous aneurysm have been reported (RÖSCH & BRET 1965 LEGRÉ et coll 1968 COLARDYN et coll 1972 GRANNIS et coll 1973)

Islet cell tumors and cystadenomas two pancreatic tumors with rich vascularization do not present rapid venous drainage and have other specific properties that differentiate them from telangiectatic lesions (BOIJSEN & SAMUELSSON 1970)

Splenic artery aneurysms are often multiple in patients with hereditary telangiectasia and may be located on the main trunk hilar and intrasplenic branches (SCHUSTER 1937 HALPERN et coll 1968 MENANTEAU 1969) The cause of these aneurysms is obscure If the disease affects only small vessels malformations of the vasa vasorum could explain the aneurysm formation On the other hand a primary defect in the support tissue within the walls of large vessels is also possible High blood flow might act as an additional factor as well as portal hypertension in splenic artery aneurysms (BOIJSEN & EFSING 1969 KREEL 1974)

Intestinal telangiectasia may appear as arteriovenous fistulas localized arteriovenous malformations diffusely scattered lesions indicated by early filling of veins and phlebectasia (GOUDEMAND et coll 1968 HALPERN et coll 1968 CAMPBELL et coll 1970 SIMEK et coll 1972)

SMITH & BARTHOLEMEW (1963) reported gastrointestinal hemorrhage in 13 per cent of patients with hereditary telangiectasia Blood transfusions were required in 90 per cent of the cases Gastrointestinal hemorrhages in those patients tend to become more frequent and severe in the later decades of life and have proved to be both a diagnostic and a therapeutic problem The telangiectatic lesions are difficult



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Intestinal telangiectasia may appear as arteriovenous fistulas localized arteriovenous malformations diffusely scattered lesions indicated by early filling of veins and phlebectasia (GOUDEMAND et coll 1968 HALPERN et coll 1968 CAMPBELL et coll 1970 SIMEK et coll 1972)

SMITH & BARTHOLEMEW (1963) reported gastrointestinal hemorrhage in 13 per cent of patients with hereditary telangiectasia Blood transfusions were required in 90 per cent of the cases Gastrointestinal hemorrhages in those patients tend to become more frequent and severe in the later decades of life and have proved to be both a diagnostic and a therapeutic problem The telangiectatic lesions are difficult

to detect during surgery which has resulted in blind bowel resections often with poor results (BRULSGAARD & JUHL 1974). Therefore angiography should be carried out in an attempt to localize the bleeding source. If lesions are observed it seems reasonable to accept them as a cause of bleeding but if no shunting or extravasation is noted the site and cause cannot be defined. In the latter situation magnification technique and pharmacoangiography may be helpful (NUSBAUM et coll. 1969, SIMEK et coll. 1972, NOVAK 1974). When multiple telangiectatic areas are present it is impossible to define the current bleeding source. Only with brisk bleeding and acute angiography it is possible to establish the exact site. Since multiple lesions may be present in the abdominal organs, selective angiography of all splanchnic arteries should be carried out.

In addition to enteric telangiectasia, gastrointestinal hemorrhage in these patients may be the result of (1) rupture of liver telangiectasia into the bile ducts resulting in hemobilia, (2) an analogous phenomenon in the pancreas, (3) varicosity due to portal hypertension, (4) ulcer, (5) carcinoma, (6) epitaxis and (7) hemoptysis. It is still under debate whether the reports of gastric and duodenal ulcers and carcinoma point to a true causal relationship or not (VON GUTZOW et coll. 1969, JACOBSEN & KRAUSE 1970, MCCAFFERY & LILLY 1975). Besides liver cirrhosis, portal hypertension may be caused by pancreatic and splenic arteriovenous fistulas.

The frequency of pulmonary telangiectasia has been estimated to approximately 15 per cent in patients with hereditary telangiectasia (HODGSON et coll. 1959). The lesions appear as single or multiple arteriovenous fistulas, as communications between a number of dilated vessels in a localized area or as the disperse telangiectatic type with numerous telangiectatic lesions widespread in both lungs (UTZON & BRANDRUP 1973, CARON et coll. 1974). In the latter form the chest film may be normal demonstrating increased vascular markings or a reticulonodular appearance. In the disperse type, even in patients with severe symptoms, the pathologic condition may escape detection during angiography and special attention must be paid to the peripheral vessels.

Bronchial arteries may also be affected in hereditary telangiectasia (TUMA et coll. 1975). The reason for the aneurysmatically dilated bronchial arteries in Case I has been discussed by TRELL et coll. (1972). They assumed that a primary communication between the bronchial arteries and the pulmonary vessels with longstanding high blood flow could explain the aneurysmatic dilatation instead of just a compensatory mechanism to the pulmonary hypertension.

Patients with hereditary telangiectasia should regularly have a radiographic control of the chest in order to detect symptomless pulmonary arteriovenous fistulas, since surgery has been recommended to prevent sudden complications such as rupture and cerebral affections (SCHUMACHER & WALDHAUSEN 1963, STANLEY & HUNTER 1970). However, it should be recognized that in the presence of cerebral symptoms angiography should be carried out to exclude cerebral telangiectasia (THOMAS & CARTY 1975, WALLER et coll. 1976).

Pulmonary arteriovenous fistulas per se have proved to be of telangiectatic origin in 40 to 60 per cent of the cases (MENANTEAU 1969) This is an indication for angiography when symptoms or signs of uncertain etiology are present from other organs in such a patient

The terminology of the vascular malformations indicated by angiography varies a great deal which is confusing Since the effect of the vascular structures is shunting of blood and this constitutes the main angiographic feature these lesions could simply be described as arteriovenous malformations or fistulas from a radiographic point of view Furthermore, it is impossible to differentiate vascular malformations of different etiology by angiography

Terms like angioma hemangioma etc concerning hereditary telangiectasia seem to be incorrect since the vascular malformations probably are the result of dilatation of pre-existing vessels with defective walls and not a new growth

SUMMARY

Hereditary hemorrhagic telangiectasia is a vascular disorder with stigmata in any part of the body The most frequently reported sites of internal lesions are the lungs liver and gastrointestinal tract When one lesion is observed on chest radiography or on splanchnic angiography there is reason to include other vascular areas in the investigation A normal angiographic finding does not exclude the presence of telangiectasia

ZUSAMMENFASSUNG

Die familiare hamorrhagische Telangiektasie ist eine vaskulare Erkrankung mit Stigmata in allen Teilen des Korpers Die inneren Lasionen treten am meisten in Lunge Leber und Verdauungskanal auf Wenn Rontgenuntersuchung des Thorax oder Angiographie des Splanchnicusgebietes solche Veranderungen gezeigt hat sollten auch endere vaskulare Gebiete untersucht werden aber normale angiographische Befunde schliessen nicht das Vorhandensein einer Telangiektasie aus

RESUME

La telangiectasie hemorragique hereditaire est une affection vasculaire qui a des localisations dans toutes les parties du corps Les sieges les plus fréquemment observés de lesions internes sont les poumons le foie et le tube digestif Quand on observe une lesion sur une radiographie pulmonaire ou sur une angiographie viscérale il y a lieu d inclure les autres territoires vasculaires dans l examen Une angiographie normale n exclut pas la presence de telangiectasie

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EARLY VENOUS FILLING IN TRANSPLANTED KIDNEYS

LEENA LAASONEN BORIS KOCK and MARCUS NYBERG

Angiography of transplanted kidneys occasionally discloses an intense early venous filling (KAUDE et coll 1970 ROSENBERGER et coll 1970) In dogs with unmodified allograft rejection (VINIK et coll 1969) as well as terminal renal disease (BECKER et coll 1970 BRAEDEL & SCHINDLER 1974) and in epidemic nephropathy (LUNDSTROM 1975) early venous filling has also been observed at selective angiography No generally accepted explanation of this phenomenon has been given but altered haemodynamics and the existence of vascular anastomoses have been suggested

Three intrarenal compartments with different rates of blood flow have been distinguished namely the cortex and the outer and inner medulla (TRUETA et coll 1947 HATCH & JOHNSON 1969) A redistribution of the blood flow away from the outer cortex is well documented in experimental shock (KUPIC & ABRAMS 1968 ELKIN et coll 1971 LAVENDER & SHERWOOD 1972) and clinically in acute renal failure including transplant failure (HOLLENBERG et coll 1968 1972)

ALMGÅRD et coll (1966) have demonstrated true arteriovenous communications in dogs with allograft rejection Immunosuppressive treatment could retard the formation of these communications or perhaps induce their healing (ALMGÅRD et coll 1967) CLARK et coll (1974) found that arteriovenous shunting was one of the earliest microangiographic findings in unmodified rejection in dogs

The aim of this investigation was to analyse whether early filling of the renal transplant vein could be used for differential diagnosis or prognostic evaluation

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Table 1

Cortical circulation presented by a score

Score	Early venous filling	No early venous filling		
		No rejection	Reversible rejection	Irreversible rejection
6	3	4	1	0
5	6	4	0	1
4	9	2	2	0
3	8	0	3	1
2	1	0	4	5
1	0	0	0	1
0	0	0	0	2
Mean score	4 1	‹ 2	3 1	1 9

Table 2

Clinical and angiographic diagnosis (figures in italics indicate diagnostic agreement)

Clinical diagnosis	Angiography		
	No rejection	Acute rejection	Chronic rejection
No rejection	*8*	1	0
Acute rejection	5	*10*	1
Chronic rejection	0	0	[illegible]

Material and Methods

Between May 1973 and September 1975 222 angiographies were performed in 193 patients with renal transplants. Early venous filling occurred on 27 occasions in 24 patients.

The angiography was carried out by ipsilateral catheterization of the femoral artery. Twenty ml of Isopaque 60 ° was injected at the orifice of the internal iliac artery at a rate of 12 ml/s. The indication for all examinations was transplant dysfunction.

Venous filling in less than 5 seconds after beginning of injection was regarded as pathologic (BECKER et coll.).

The radiologic diagnosis was made without considering the time for appearance of the veins and without knowledge of clinical findings. The diagnosis was acute rejection when the arteries were stretched suggesting oedema, or when a prolonged arterial circulation time, a poor nephrographic effect, or poor filling of the inter

a

b

c

Fig 1 A sudden decrease of diuresis led to angiography on the first postoperative day Angiographic diagnosis Ischemic injury Later chronic rejection developed a) Normal interlobar and arcuate arteries slightly prominent interlobular arteries b) Faint filling of veins 2 5 s after beginning of injection c) Intrarenal veins well demonstrated at 4 s Evident nephrographic effect

lobular arteries in magnification films were noted (FOLEY et coll 1975) Chronic rejection was diagnosed when a general narrowing of the arteries with irregularities and occlusions was present The arterial circulation time was determined from the point where the contrast medium entered the renal artery to the point where the renal arteries were cleared of the medium The excretion of the medium was recorded on delayed films

A scoring system was developed to obtain an impression of the cortical circulation using the arterial circulation time degree of filling of the interlobar arteries and degree of the nephrographic effect An arterial circulation time of 2 s or less was regarded as normal (KAUDE et coll) and received 2 points between 2 5 and 3 5 s 1 point and 4 s or more suggesting irreversible failure (LAASONEN 1977) 0 point Both the filling of the interlobular arteries and the degree of the nephrographic effect were graded as normal (2 points) impaired (1 point) or absent (0 point) Thus a maximum score of 6 points was obtained for an angiographically normal transplant and a score of 0 point for a kidney with severely impaired circulation

In 6 patients with early venous filling a percutaneous needle biopsy containing vital cortical tissue from the transplant was performed within 2 weeks of the angiography The maximum time limit of 2 weeks was chosen arbitrarily The biopsy specimens were re-examined and re evaluated without knowledge of angiographic or clinical findings Special attention was paid to vascular and glomerular abnormalities

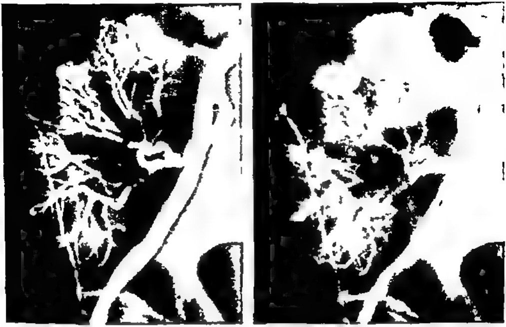
Results

Early venous filling was observed on films from 1 day to 2 years after transplantation Repeat angiography was performed twice in 8 patients and three times in one patient Early venous filling occurred in 3 of these patients with an interval of 1 to 7 months between the examinations in 3 patients only at the second angiography In another 4 patients early venous filling disappeared at a repeat angiography where the peripheral circulation had been impaired

The score was also calculated for 30 patients without early venous filling Of these patients 10 had no clinical evidence of rejection 10 had a reversible rejection period and 10 had irreversible rejection (Table 1) Early venous filling occurred at scores 6–3 which should predict adequate graft function and only once at score 2 The clinical and angiographic diagnoses are presented in Table 2

Nine patients had no clinical signs of rejection (Fig 1) 2 had oliguric renal failure postoperatively 6 were recovering from mild ischaemic injury, and one was examined because of persisting hypertension One of these grafts never functioned 3 patients later lost their grafts in rejection, and 5 patients had satisfactory renal function for over 1 year with a serum creatinine level of under 2 mg per cent

Acute rejection was present at the time of 16 examinations (13 patients Fig 2) The diagnosis was confirmed at microscopy in 7 rejection episodes and was indicated in the remaining 9 cases by the clinical course and the response to immunosuppressive



a b

c

Fig 2 Acute irreversible rejection started on the 18th postoperative day Angiography on the 23rd day Angiographic diagnosis Severe rejection a) Arterial phase Decreased number of vessels with irregular lumen b) Simultaneous filling of arteries and veins at 3 s c) Intense filling of the veins Poor irregular nephrographic effect

Table 3

Time of transplant function in patients with transplants from non living donors

Time	Early venous filling (per cent in parentheses)	
	Present	Absent
0–29 days	3 (13 0)	20 (21 3)
1–12 months	7 (30 5)	21 (22 3)
1 year	13 (56 5)	53 (56 4)
No of patients	23	94

treatment Of these 13 patients 5 lost their grafts immediately 1 after 6 months 2 had a progressive chronic rejection with poor graft function and only 3 patients had satisfactory renal function for more than one year Two patients died from non renal disorders while the rejection still continued

The 2 patients with chronic rejection both had a progressive impairment of their renal function and both lost their grafts within 6 months after the detection of the early venous filling

Early venous filling occurred in only one patient with a graft from a living relative Therefore graft survival was compared only in patients with grafts from non living donors (Table 3) No significant difference in graft survival was detected between the 2 groups

Arterioles and at least one artery of interlobular size or larger were found in all biopsy specimens at microscopy The vessels were normal in one specimen The pathologic findings ranged from a very slight increase in intimal thickness and fibrinoid degeneration (2 specimens) to inflammatory infiltration and necrosis of the vessel wall (1 specimen) Interstitial oedema and cellular infiltration were found in 5 specimens and the abnormalities were severe in 2 Slight to moderate epithelial degeneration of the tubuli was present in 5 and in 3 specimens some hyalinized and sclerotic glomeruli Focal glomerular necrosis or mesangial proliferation was present in 2 specimens

Discussion

Early venous filling may be due to technical artifacts as ELKIN et coll pointed out If a large bolus of contrast medium is injected selectively into a small artery simultaneous filling of the artery and vein occurs In the present material selective catheterization was not used and the amount of contrast medium in the common iliac artery did not exceed 20 ml the possibility of such artifacts is therefore eliminated

KAUDE et coll suggested that the increased filling of the renal transplant vein was

due to the absence of contrast excretion They considered filling of the renal vein to be a criterion of actue tubular necrosis Other authors have not been able to confirm this statement (HOLLENBERG et coll 1968 VOEGELI et coll 1974) In the present series early venous filling and contrast excretion occurred in 6 of 27 angiographies Thus absent excretion of the contrast medium could not account for early venous filling in these cases

BECKER et coll suggested that early venous filling was due to a redistribution of the intrarenal blood flow Such a redistribution has been observed both in oliguric transplant failure and in rejection (HOLLENBERG et coll 1968) but early venous filling was not observed A functional constriction of the preglomerular vessels was suggested by HOLLENBERG et coll An angiographic appearance consistent with such a vasoconstriction was described by FOLEY et coll The interlobular arteries were relatively prominent and the glomerular filling was slowed This appearance was demonstrated in some of the patients suggesting that a redistribution was present However whether or not a redistribution accounts for the early venous filling is uncertain

In epidemic nephropathy early venous filling occurs in kidneys with satisfactory peripheral circulation LUNDSTRÖM suggested that the mechanism was an increased cortical circulation A marked vasodilatation has been observed after uncomplicated renal transplantation in man (KOUNTZ et coll 1970 HOLLENBERG et coll 1972) This could be the mechanism of early venous filling in the early postoperative phase in patients with very mild ischaemic injury of functioning transplants

ALMGÅRD et coll (1966) have demonstrated the development of arteriovenous communications in the renal cortex between preglomerular and postglomerular arteries and veins in unmodified rejection in dogs The development of such communications also in man is a possible explanation of early venous filling in rejection Although in vivo serial magnification angiography has improved cortical veins have not been demonstrated The chance of seeing such a communication in a percutaneous needle biopsy specimen is also minimal

A direct arteriolo arteriolar pathway has been demonstrated in the kidney (LJUNGQVIST 1964) In the juxtamedullary glomeruli the glomerular capillaries extend as lateral branches from a continuous arteriole This arrangement may be regarded as a potential regulatory mechanism for the glomerular filtration rate and for the medullary blood flow However it is uncertain whether it is of sufficient magnitude to produce early venous filling unless there is extensive loss of cortical tissue In the present patients early venous filling disappeared when the cortical circulation was impaired

The histologic findings agreed with those reported for human renal transplants (PORTER 1974) No features could be considered specific for the patients with early venous filling

Early venous filling was observed in 12 2 per cent of the examinations performed in renal transplant recipients It was predominantly found in grafts obtained from

non living donors The presence of early venous filling could not be used for differential diagnosis as it occurred in acute or chronic rejection as well as in cases without any clinical evidence of rejection The diagnostic accuracy without considering the venous filling was rather good (Table 2)

Early venous filling could not be used directly in the estimation of the prognosis It was found in transplants with angiographic features suggesting adequate cortical perfusion (scores 6–3) In spite of this when early venous filling occurred in connection with rejection the rejection was often severe and the graft survival was poor Only 3 of 13 patients with rejection and early venous filling recovered satisfactory renal function

SUMMARY

Early venous filling in patients with renal transplants was found in the presence of ischaemic injury acute rejection and chronic rejection thus it cannot be used in differential diagnosis Early venous filling was present only when the cortical circulation was scored as adequate although when observed in acute or chronic rejection the prognosis for the graft was poor

ZUSAMMENFASSUNG

Eine fruhzeitige Fullung der Venen bei Patienten mit Nierentransplantaten wurde bei Gegenwart von ischamischen Schaden einer akuten Abstossung und einer chronischen Abstossung gefunden Diese kann deshalb nicht differentialdiagnostisch verwendet werden Die fruhzeitige venose Fullung war nur dann vorhanden wenn die kortikale Zirkulation als adaquat beurteilt wurde obwohl wenn sie bei akuter oder chronischer Abstossung beobachtet wurde die Prognose fur das Transplantat schlecht war

RÉSUME

Les auteurs ont constate un retour veineux précoce chez les transplantes renaux dans les cas de lesion ischemique de rejet aigu et de rejet chronique Ce signe ne peut donc pas servir au diagnostic différentiel Le retour veineux precoce n est present que quand la circulation corticale est considerée comme adequate mais quand il est observe dans le rejet aigu ou chronique le pronostic de le transplantation est mauvais

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FROM THE LABORATORY OF EXPERIMENTAL RADIOLOGY HOPITAL CARDIOVASCULAIRE ET PNEUMOLOGIQUE F 69394 LYON FRANCE

EFFECT OF METHYLGLUCAMINE SALTS OF IOCARMIC AND IOTHALAMIC ACIDS ON HEMODYNAMICS, ACID-BASE EQUILIBRIUM AND COAGULATION

M AMIEL R BARBE and R DUC

A better knowledge of the reactions to contrast media used in angiography implies an analysis of the different modifications of physiologic parameters as a function of the injection conditions (the quantity administered by a single injection and the total quantity during the same examination)

Numerous experiments concerning the hemodynamic parameters and ionic variations and acid-base equilibrium have been achieved in animals (GIAMMONA et coll 1963 BERNSTEIN et coll 1964 ISERI et coll 1965 BJÖRK 1966 GONZALES & STIERITZ 1966 HILAL 1966 KLOSTER et coll 1966 LEVIN et coll 1969 BECKER et coll 1973 ROSENTHAL et coll 1973) On the other hand those devoted to modifications of coagulation factors are rare (BERNSTEIN & GANS 1966 STEIN & HILGARTNER 1968)

The modifications with time of a series of hemodynamic and ionic parameters and of the acid-base equilibrium as well as thromboelastogram parameters were investigated in 10 dogs after a rapid massive intra aortic injection (3 ml/kg) of a contrast medium used in angiography (methylglucamine salt of the iothalamic acid) and of the corresponding dimer (methylglucamine salt of the iocarmic acid)

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Similar or larger amounts of contrast media have previously been used in animal experiments (BERNSTEIN & GANS, GONZALES & STIERITZ). Such a large dose is not utilized in a single injection in man but it represents a compromise between maximum single dose injection (2 ml/kg) and maximum total quantity (4 ml/kg) injected at cardiac angiography in newborns.

Material and Method

Ten dogs were used, with a mean weight of 13.5 kg (range 12 to 17 kg). With an interval of 5 days, one of the contrast media was injected in the first experiment and the other in the second. In order to obtain homogeneity of the results, the order of injection of the contrast media (monomer and dimer) was reversed in every second dog.

The two contrast media had the same iodine concentration and the same amount was used in each experiment (3 ml/kg). The following parameters were analysed after the injection:

continuous ECG and blood pressure recording;

successive blood samplings during 30 min to determine the pH, the PaO_2, the $PaCO_2$, the sodium and potassium levels in the blood, and the osmolality;

measurement of blood volume using the radioactive tracer dilution method (serum albumin marked with $^{99}Tc^{m}$) and the hematocrit;

coagulation estimation by means of the thromboelastogram.

The operative procedure in each experiment was as follows. The dog was under general anesthesia (intravenous phenobarbital injection), and with spontaneous respiration. A catheter was placed in the ascending thoracic aorta and used for the injection of the contrast media and for the different subsequent samplings. Another catheter was placed in the descending aorta for the continuous blood pressure recording and for sampling to determine coagulation. The contrast medium (3 ml/kg) was injected with a constant pressure syringe (a 50 ml de Caillon syringe) at the maximum possible injection rate (2 s on the average). Seven blood samplings were performed before, and 30 s and 1, 3, 10 and 30 min after injection, in certain cases also several hours after the injection, but only to determine coagulation parameters.

The pH, PaO_2 and $PaCO_2$ measurements were done with a Ratermeter chain and the measurement of osmolality by the cryoscopic method. Sodium and potassium levels were measured by means of a flame spectrophotometer, and coagulation was determined with a Hellige thromboelastograph. ECG and blood pressure were recorded with a Sandborn apparatus using a Statham pressure head.

Results

The *blood pressure* was not significantly modified after the dimer injection, but the monomer induced a systolic and diastolic pressure decrease and a considerable

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Table 2

Variations of hematocrit and osmlality (mean values) following monomer and dimer injections

	Hematocrit		Osmolality	
	Monomer	Dimer	Monomer	Dimer
Pre injection	35	34	302	311
30 s	28	26	306	324
1 min	30	25	308	325
3 min	33	26	305	312
10 min	25	29	297	307
30 min	29	35	296	304

The *blood volume* increased following injection of both media (maximum 20% for the monomer and 27% for the dimer) due to increase of the plasma volume simultaneously with decrease of the hematocrit (Table 3) The return to normal was rapid after the dimer injection (at the tenth min) while for the monomer the blood volume was increased by 20 per cent at the tenth min

Effect on coagulation An earlier and more intense lengthening of the coagulation time was found after the dimer than after the monomer injection (Table 4) The return to normal occurred more rapidly after the former

Discussion

In the literature only one report on the vascular effects of contrast media of the dimer type has been found (GONZALES & STIERITZ) They analysed only the effects of the dimer on the output and pressure in the aorta the femoral artery and the carotid artery It was found that the dimer had less influence than the monomer This is in conformity with the present results

The effect on the pH was found to be different for the two media The dimer medium caused an insignificant modification only but the monomer a pH decrease of 0 08 at the first min and a normal value was not yet attained at the thirtieth min BECKER et coll administered doses of less than 1 ml/kg to adults and ROSENTHAL et coll doses of 1 3 ml/kg to children and did not find significant variations With higher doses ROSENTHAL & MESROBIAN (1975) reported results comparable to the present ones decrease of pH with a peak at the first min and an increase rapid until the third min and slow until the tenth min

The PaO and $PaCO_2$ reacted differently A return to normal value was achieved faster following the dimer injection and the amplitude of the effect was less significant for this medium

ROSENTHAL et coll and BECKER et coll did not observe any modification of the $PaCO_2$ value after use of the monomer On the other hand ROSENTHAL & MESROBIAN

Table 3

Effect on blood volume The normal value is 100 per cent

	Pre injection	30 s	1 min	3 min	10 min
Monomer	100	115	120	118	120
Dimer	100	113	127	113	100

noted a decrease of PaO slowly returning to normal at the fortieth min This result thus agrees with the present one The effect may be explained by a deviation to the left of the oxyhemoglobin dissociation curve this modification is especially noticeable from the first to the third min and is secondary to the fall in blood pH (ROSENTHAL & MESROBIAN) However in the present experiments the dimer caused an increase of the PaO_2

No significant modification of the sodium level was observed by GIAMMONA et coll LEVIN et coll or BECKER et coll but the quantities administered were about 1 ml/kg The present results may be explained by the much higher amounts of the contrast media used

The increase of the blood osmolality and of the blood volume and the decrease of the hematocrit are at least partially explained by the hyperosmolality of the contrast media which produces a dilution of the blood by extravascular fluid Most authors have found a hyperosmolality peak between the first and the third min (GIAMMONA et coll KLOSTER et coll BRISTOW et coll 1967 LEVIN et coll BECKER et coll ROSENTHAL et coll) as in the present experiments BRISTOW et coll BECKER et coll and ROSENTHAL et coll found that the osmolality returned to normal between the fifth and the fortieth min with 0 5 to 1 ml/kg However in the present experiments a secondary decrease with a late return to normal was observed Such a diphasic effect was also reported by LEVIN et coll

Many authors (FRIESINGER et coll 1965 BERNSTEIN & GANS BJÖRK KLOSTER et coll LEVIN et coll BECKER et coll ROSENTHAL et coll) have found a decrease of the hematocrit values with a peak between the first and the third min The return to normal varies especially during the first ten min The present results agree with those previously reported

Reports on blood volume are rare ISERI et coll and KLOSTER et coll noted a 5 to 10 per cent increase in the blood volume at 5 min after injection but they did not record the development with time In the present experiments a more varying increase following the dimer than the monomer injection was found but due to the higher amounts of contrast medium used the effect was generally more evident

The depressive effect of the contrast media on the blood coagulation is little known the effect varies but is often of long duration In the present experiments a depression of the coagulation factors of the same degree occurred after both the monomer and dimer injections Twenty minutes after intravenous injection of Hypaque (5 ml/kg)

Table 4

Thromboelastography Coagulation time (mean values)

	Pre injection	30 s	1 min	3 min	10 min	30 min
Monomer	10	13	16	20	16	11
Dimer	10	15	23	14	12	11

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in dogs BERNSTEIN et coll found a 25 per cent decrease of the thrombin time and of the fibrinogen blood concentration This effect could not be due to dilution because it did not occur after a dextran perfusion giving the same hematocrit decrease On the average the coagulation time is twice as long as before injection from the first min and a return to the pre injection value is not obtained before the thirtieth min

SUMMARY

The effects on electrolytes osmolality pH PaO PaCO, hematocrit blood volume and coagulation occurring after a rapid intra aortic injection of a monomer and a dimer (salts of methylglucamine of the iothalamic and iocarmic acids) were compared The effects of the monomer agreed with previous results but the effects of the dimer differed from those reported in the literature

ZUSAMMENFASSUNG

Die Wirkung auf Elektrolyten, Osmolalitat pH PaC, PaCO Hamatokrit Blutvolumen und Koagulation nach einer raschen intraaortischen Injektion eines Monomers oder eines Dimers (Salze von Methylglucamin der Iothalaminsaure und der Iocarminsaure) wurden verglichen Die Effekte von Monomeren stimmen mit denen in der Literatur berichteten Resultaten überein, die Effekte von Dimeren unterscheiden sich jedoch

RESUME

Les auteurs ont compare les effets d une injection intraaortique rapide d un monomere et d un dimere (sels de methylglucamine des acides iothalamiques et iocarmiques) sur les electrolytes l osmolarite le pH la PaO la PaCO l'hematocrite le volume sanguin et la coagulation Les effets du monomère ont ete conformes aux resultats precedents, mais les effets du dimère ont differes de ceux qui sont publies dans la litterature

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EFFECT OF RESPIRATION ON CARDIAC MOTION DETERMINED BY CINEANGIOGRAPHY

Implications concerning three-dimensional heart reconstruction using computer tomography

H G BOGREN B M T LANTZ R R MILLER and D T MASON

Computer tomography of the head has been called the most important advance in radiology since the discovery of the roentgen rays (LINDGREN 1975) and is now a well established diagnostic tool The logical development from head scanners is whole body or general purpose scanners which are now being used in chest diagnosis (KREEL 1976) One of the limitations of body scanners is the long scan time and therefore mobile organs like the heart have not been able to be examined in the past Certain research groups are presently developing special heart scanners (ROBB et coll 1974 LANTZ et coll 1975) Different methods can be used but in any method where more than one heart cycle is involved for the collection of data the recordings necessitate gating to the cardiac cycle This can easily be accomplished (BERMAN et coll 1975) but if a large number of cardiac cycles have to be used respiratory motion of the heart will probably also influence the spatial resolution of the reconstructed images

The influence of respiration and respiratory maneuvers on blood pressure heart rate blood flow and heart murmurs has been the basis of many investigations

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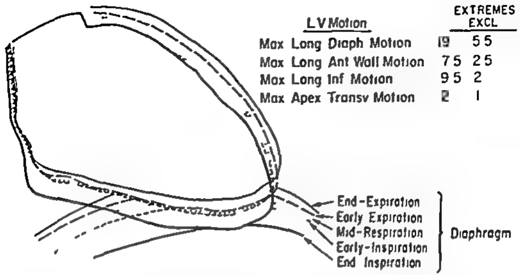

Fig. 1 Five consecutive end-diastolic tracings of the left ventricular contour and the left hemi diaphragm during shallow breathing in the right anterior oblique view All measurements in mm The timing of diaphragmatic motion corresponds temporally to left ventricular end-diastolic volume movement as indicated by the specific silhouette markings throughout the respiratory cycle Extremes excluded means measurements in which inspiratory and expiratory levels of respiration were excluded For abbreviations see Table 1

(BRECHER & HUBAY 1955 ANGELONE & COULTER 1965 DAVIES & NEILSON 1967, LEVIN et coll 1962 GUNTHER & BOHM 1973 BUCHER 1963) It is a well known fact among thoracic surgeons and radiologists that the heart moves with respiration but very little has been documented in this regard (DOUGHERTY 1970) Moreover no actual measurements of cardiac respiratory motion have been found in the literature Such an investigation was therefore undertaken and is now reported

In the first part cardiac respiratory motion per se was investigated using selective cineangiography In the second part the influence of respiratory motion on the resolution in three-dimensional reconstruction of the heart using a large number of cardiac cycles was evaluated

Material and Methods

Part 1 The first part is based on 39 routine cardiac cineangiographies in 23 patients 14 children and 9 adults The cineangiography was recorded at 64 frames per second using Philips biplane equipment with cesium iodide image intensification In all patients except 2 contrast medium was injected into one cardiac chamber, and in 2 patients metallic prosthetic valves were used as tracers

All children were sedated and the recordings were performed during free normal breathing In the adults the recordings were made during normal or shallow breathing with the arms raised to decrease diaphragmatic movement The diagnosis in the adult

Table 1

Measurements (in mm) of diaphragmatic and left ventricular movements in 5 adults during shallow or normal (Case 3) breathing recorded in the right anterior oblique projection Max long diaphr = maximum longitudinal diaphragmatic ant wall = anterior wall of left ventricle inf wall = inferior wall of left ventricle max trans = maximum left ventricular apical transverse motion

	Beats	Max long diaphr movement	Inspir and expir excluded	Max long ant wall movement	Inspir and expir excluded	Max long inf wall movement	Inspir and expir excluded	Max trans movement	Inspir and expir excluded
Case 1									
End-diastole	6	13	8.5	9	4	9.5	5	6	3.5
End-systole	6	13	8.5	8	3.5	6.5	3.5	6	3
Case 2									
End-diastole	4	16	8	6	2	6	3.5	5	2
End systole	4	16.5		5		7		5	
Case 3									
End-diastole	5	16	6	9.5		10.5		10.5	
End-systole	5	15	5.5	7	3	6.5	2.5	7.5	3
Case 4									
End-diastole	6	18	5	14	4.5	14	3	8	3
End systole	6	13.5	8	8	2.5	8	3	3	3
Case 5									
End-diastole	5	19	5.5	7.5	2.5	9.5	2	2	1
End systole	4	10	4	4	2	4.5	1.5	2	1
Average	5	15 *(10–19)*	6.5 *(4–8.5)*	8 *(4–14)*	3 *(2–4.5)*	[illegible] *(4.5–14)*	3 *(1.5–5)*	5.5 *(2–10.5)*	2.5 *(1–3.5)*

patients was either normal or coronary artery disease and in children congenital heart disease

The cineangiography was projected frame by frame and either the end systolic or end diastolic contour of the cardiac chamber was traced together with the hemidiaphragm closest to the chamber A series of end systolic and end diastolic tracings at different phases of respiration were obtained and measurements of diaphragmatic and cardiac chamber motion were performed and corrected for magnification (Fig 1)

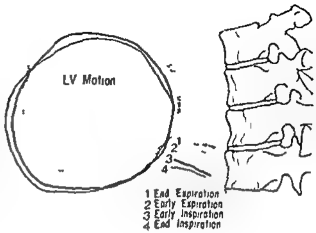

Fig 2 Four consecutive end diastolic tracings of the left ventricular contour and the left hemidiaphragm in an adult during shallow breathing in the left anterior oblique view Left hemidiaphragmatic movement is 11 mm Wall of left ventricle moves 9 5 (diaphragmatic wall) to 6 5 mm (posterior lateral wall) in a craniodorsal direction and rotates clockwise

Evaluation consisted of high quality films in which only the chamber selectively injected with contrast medium was traced thereby assuring accurate analysis In addition only consecutive regular beats were used The accuracy of the tracings was found to be within 1 mm by repeat determinations

In the two patients with prosthetic valves in whom cineangiography was performed the end systolic and end diastolic positions of the valves were traced together with the hemidiaphragm closest to the valve

Part 2 In the second part 30 very short runs of cineangiography were performed in the 2 patients with prosthetic valves who were instructed to hold their breath in mid respiration inspiration and deep inspiration five times in each position The hemidiaphragm was traced together with the prosthetic valve in end systole and end diastole

In another 25 patients who underwent routine cardioangiography holding their breath in mid inspiration the end diastolic or end systolic contour of the injected cardiac chamber was traced together with the hemidiaphragm closest to the traced chamber

Results

Cardiac respiratory motion per se

Left ventricle Table I is from the first series of 5 adult patients in whom diaphragmatic and left ventricular wall motions were measured from routine left ventricular cineangiograms in the right anterior oblique view recorded during shallow breathing or in one case normal breathing An average of 5 consecutive beats was trac d and measured in end systole and end diastole An example of the tracings and measurements is given in Fig 1 The average maximum longitudinal (craniocaudal) diaphragmatic motion was 15 mm with a range of 10 to 19 mm The average maximum longi

Table 2

Measurements (in mm) of diaphragmatic and left ventricular end-diastolic motion in 5 children during free respiration recorded in the lateral projection (for abbreviations see Table 1)

Age	Beats	Max long diaphr movement	Max long ant wall movement	Max long inf wall movement	Max septal wall p a movement
1 day	5	7	3	4	2 5
1 day	4	5	2 5	1 5	1 5
3 years	4	7	2 5	6	4 5
6 5 years	2	3 5	1 5		2
2 months	3	7	2 5	4 5	4
Average	3 6	6 (3 5–7)	2 5 (1 5–3)	4 (1 5–6)	3 (1 5–4 5)

tudinal anterior wall motion was 8 mm with a range of 4 to 14 mm The inferior wall moved nearly the same extent and the maximum transverse motion was 5 5 mm with a range of 2 to 10 5 mm

Measurements of left ventricular motion were also made from the left anterior oblique view in another 3 adult patients recorded during shallow respiration The diaphragm moved 6 5 to 18 mm with an average of 12 mm The left ventricle moved cranially 5 to 10 5 mm average 8 mm The left ventricular outflow tract moved cranially 4 to 6 mm average 5 mm In 2 patients the left ventricle moved also in a dorsal direction (Fig 2) in the third patient in a straight cranial direction

Measurements from the lateral view of the left ventricle in end diastole in 5 children appear in Table 2 The recordings were obtained during free respiration while the children were mildly sedated An average of 3 6 beats were measured in each individual The average maximum longitudinal diaphragmatic motion was 6 mm with a range of 3 5 to 7 mm The maximum longitudinal anterior wall motion of the left ventricle was 2 5 mm with a range of 1 5 to 3 mm the inferior wall motion was 4 mm with a range of 1 5 to 6 mm and the maximum septal wall anterior posterior motion was 3 mm with a range of 1 5 to 4 5 mm

It was also apparent from the lateral views of the left ventricle in children that in 2 newborns and one 3 year old child the left ventricle moved in a cranial and ventral direction (Fig 3) In 3 other children 4 years and older the left ventricle moved in a cranial dorsal direction as was observed in the adults The heart rotates clockwise in both categories children and adults the axis being more superiorly located in small children than in larger children and adults

Multiple cardiac chambers The measurements from another 5 children 3 being newborns are summarized in Table 3 The measurements were made from postero-anterior or right anterior oblique views of the left ventricle the right ventricle or the

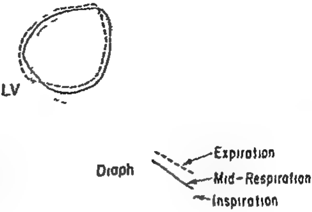

Fig. 3. Three consecutive end diastolic tracings of the left ventricular contour and left hemidiaphragm in a newborn child during free respiration recorded in the *lateral projection*. Wall of left ventricle moves in a cranioventral direction and rotates clockwise.

right atrium. An average of 4.4 beats/patient were measured and the measurements obtained were approximately the same as those obtained from the lateral view in children. The maximum longitudinal diaphragmatic motion was 7 mm and the overall chamber motion varied between an average of 4 and 4.5 mm with a range of 1.5 to 8.5 mm.

Right atrium. The right atrium was measured in 2 children in p.a. projections. It was found to move in a lateral and cranial direction, the inferior wall more than the superior wall, 4.5 and 1.5 mm, respectively, with the diaphragm at the same time moving 7.5 mm in one patient, and uniformly 1.5 in another patient with the diaphragm moving 4 mm.

Left atrium. The left atrium was measured in 2 children in lateral views and was found to move like the left ventricle.

Prosthetic valve motion. The motion of metallic aortic, mitral and tricuspid prosthetic valves was recorded in the p.a. projection in 2 adult patients. The aortic valve was found to move in a cranial and lateral direction approximately half as much as the diaphragm. The mitral valve was found to move in a cranial and lateral direction also approximately half as much as the diaphragm. The tricuspid valve was found to move in a cranial and medial direction again half as much as the diaphragm.

Motion between deep inspiration and deep expiration. The motion of the right coronary artery was measured in one patient to obtain information on the motion between deep inspiration and deep expiration. It was seen to move 8 to 13 mm in a lateral and dorsal direction with the diaphragm moving 14 mm. The inferior parts moved more than the superior parts, 13 mm for the inferior and 8 mm for the superior parts (Fig. 4).

Table 3

Measurements (in mm) in the postero-anterior and right anterior oblique views of diaphragmatic and cardiac chamber movement in end-diastole in 5 children during free respiration (for abbreviations see Table I)

Age	Beats	Max long diaphr movement	Max long sup wall movement	Max long inf wall movement	Max lat wall movement	Chamber	View
1 day	3	7 5	1 5	4 5	2.5	Right atrium	P a
1 day	3	6	4 5	4 5	5	Left ventricle	Right anterior oblique
11 years	5	9 5	7 5	8 5	3 5	Left ventricle	Right anterior oblique
1 day	4	3	2			Right ventricle	P a
5 years	7	9 5	5	4 5	4 5	Left ventricle	P a
Average	4 4	7 (3–9 5)	4 (1 5–7 5)	5 5 (4 5–8 5)	4 (2 5–5)		

Possible influence on three dimensional reconstruction of the heart

In order to determine if cardiac respiratory motion could be significantly decreased by excluding the highest and lowest levels of the diaphragm such measurements were performed in 8 patients 5 of these appear in Table 1 under Inspiration and expiration excluded Such measurements are also shown in Fig 1 under Extremes excluded The motion was found to decrease to less than half on the average but was still relatively extensive with a left ventricular average motion of 2 5 to 3 mm with individual motions of as much as 4 5 and 5 mm In the 3 patients not shown in Table 1 the average motion was approximately the same as those in the table

Breath holding In the 25 patients examined during breath holding the diaphragm did not move between different heartbeats and the left ventricle right ventricle tricuspid mitral and aortic prosthetic valves were found to stay in exactly the same place

In 2 patients who were asked to repetitively hold their breath in mid respiration inspiration and deep inspiration five times in each position the level of the diaphragm varied from 3 to 12 5 mm These patients had prosthetic valves and the valves were situated 1 5 to 5 mm apart at the different levels at which the patient carried out breath holding For comparison the difference in the valve position between end systole and end diastole was 3 5 to 7 mm Only occasionally did the patient reach the same level of inspiration twice and never three times It was further observed at

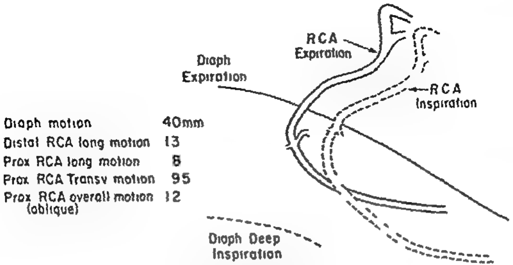

Fig. 4 Tracings of the right coronary artery (RCA) in end-diastole and the right hemidiaphragm in deep inspiration and expiration in the left anterior oblique projection

fluoroscopy of hundreds of patients that they do not reach the same diaphragmatic position when asked to hold their breath two or three different times

In 3 patients it was observed that the diaphragm during breath holding actually moved down 1 to 3 mm between end systole and end diastole of the cardiac cycle

Discussion and Conclusions

Cardiac respiratory motion per se

It is evident that the heart moves substantially with respiration During shallow or normal breathing the heart moves approximately half as much as the diaphragm the inferior parts in most patients slightly more than the superior parts During deep respiration the heart moves relatively less compared to the diaphragmatic motion than during shallow breathing

In adults a cardiac chamber may move as much as 14 mm during shallow or normal respiration as found in one patient the average being less than 10 mm The cardiac respiratory motion in children is smaller than in adults in actual measurements as expected in these bodies of smaller size It should be pointed out that occasionally cardiac motion in newborns is larger than in older children as seen in the 6 5-year old child (Table 2)

The following is a summary from measurements of cardiac respiratory motion in 39 recordings in 23 different patients Between inspiration and expiration (1) The left ventricle moves in a cranial and lateral direction and rotates either in a cranial ventral or cranial dorsal direction (2) the left atrium rotates in a cranial ventral or cranial dorsal direction as seen in the lateral view (3) the right atrium moves in a

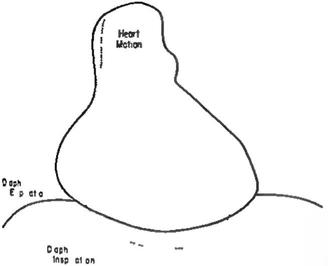

Fig. 5 Diagram of overall cardiac motion between inspiration and expiration in the p a projection

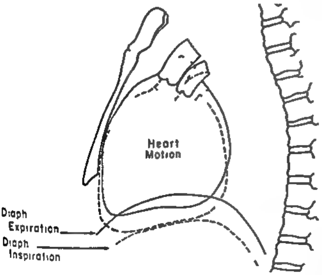

Fig. 6 Diagram of overall cardiac motion between inspiration and expiration in the lateral projection

cranial and lateral direction as seen in the p a view (4) the aortic valve moves in a cranial and lateral direction as seen in the p a view (5) the mitral valve moves in a cranial and left lateral direction as seen in the p a view and (6) the tricuspid valve moves in a cranial and left medial direction as seen in the p a view

From a composite analysis of the measurements of cardiac chamber and valve motion it is concluded that between inspiration and expiration the whole heart moves cranially the inferior part more than the superior part and appears to be somewhat compressed so that its lateral parts move in a lateral direction in the p a

projection (Fig 5) In the lateral projection (Fig 6) it moves in a cranial and ventral direction in small children and in a cranial and dorsal direction in most adults and also rotates clockwise

The heart also influences the level of the diaphragm in some patients so that during diastolic filling of the left ventricle the diaphragm may be displaced slightly in a caudal direction Such a diaphragmatic motion due to cardiac contraction or relaxation has not been described previously in the literature However such motion has been recorded for example in a communication by HIPONA & GREENSPAN (1964) in which a composite systolic and diastolic chest film was published and diaphragmatic motion is clearly observed

The motion of the left ventricle varies between small children and adults and also varies among adults (Figs 2 3) The described motion for the different heart chambers and valves is an average Individual variations probably occur as the heart is expected to follow the law of least resistance when it is moved cranially from inspiration to expiration As the heart moves it compresses the lungs and may be expected to move in a direction in which the resistance is least which must vary in different individuals depending on disparity of body constitution and the elasticity in different parts of the lungs Local scars and volume loss in the lungs also influence the cardiac respiratory motion

The hemodynamic influence of respiration has always been attributed to a change in the intrathoracic pressure between inspiration and expiration and thereby variations in the venous filling of the heart Whether cardiac respiratory motion has hemodynamic significance by pure mechanical influence remains an interesting speculation

Change in intensity of a murmur during breathing has also been attributed to changes in venous filling of the heart between inspiration and expiration As a heart valve can move more than 1 cm between inspiration and expiration cardiac respiratory motion may be an additional cause of murmur variation This hypothesis is at least partly supported by the work of LEVIN et coll (1962) who found inconsistent variations in the change in intensity of murmurs during intracardiac phonocardiography

Influence on three dimensional reconstruction of the heart

In three dimensional reconstruction of the heart using a large number of heart beats for recording the respiratory as well as the cardiac cycle should be gated to avoid significant unsharpness Shallow or normal breathing with exclusion of extreme inspiration and expiration is not likely to be sufficient The maximum motion at this procedure was found to be 5 mm and thereby would probably provide poor spatial resolution of the cardiac walls The minimum motion found was 1 5 mm which would probably also result in poor resolution of for example a valve leaflet

In addition repetitive holding of breath does not appear to be a feasible approach since the same level of respiration is not reached voluntarily

In a subsequent report important procedures for minimizing cardiac respiratory motion will be described as well as the influence of such motion for three dimensional reconstruction of the heart using multiple cardiac cycles for scanning

SUMMARY

Based on 39 cineangiographies in 23 patients performed during respiration with tracing of the cardiac chambers and the diaphragm it has been found that the heart moves significantly with respiration approximately half as much as the diaphragm during shallow or normal respiration The cardiac respiratory motion indicates that gating of the respiratory cycle as well as the cardiac cycle is necessary in three dimensional reconstruction of the heart using a large number of heart beats for recording

ZUSAMMENFASSUNG

Auf der Basis von 39 Filmangiographien bei 23 Patienten die wahrend der Atmung mit Zeichnung der Herzkammern und des Diaphragmas vorgenommen wurden wurde gefunden dass das Herz signifikant mit der Atmung bewegt wird etwa halb soviel wie das Diaphragma bei oberflachlicher oder normaler Atmung Die respiratorische Bewegung des Herzens lasst erkennen dass eine Verbindung des respiratorischen Zyklus und des Herz Zyklus zur drei-dimensionalen Rekonstruktion des Herzens unter Verwendung einer grossen Anzahl von Herzschlagen zur Registrierung notwendig ist

RÉSUME

Sur la base de 39 cineangiocardiographies chez 23 malades effectuees au cours de la respiration avec calque des cavités cardiaques et du diaphragme les auteurs ont constate que le cœur subit des deplacements importants au cours de la respiration correspondant environ à la moitie des deplacements du diaphragme au cours de la respiration superficielle ou normale Ce mouvement respiratoire du cœur montre qu il est necessaire d eliminer l effet du cycle respiratoire et aussi du cycle cardiaque pour reconstruire le cœur en trois dimensions on y parvient en enregistrant un grand nombre de battements cardiaques

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RETROGRADE PANCREATOGRAPHY IN THE PIG

Comparison of Isopaque and Amipaque

F LILLEÅS and T SWENSEN

The pancreas is one of the organs least accessible to radiography However the diagnostic possibilities were much improved during the last few years because of the introduction of endoscopic retrograde pancreatography Using an Olympus JF II fiberendoscope the papilla of Vater is identified and a teflon catheter inserted through the endoscope and into the orifice of the ampulla Contrast medium is then injected (KASUGAI et coll 1972 OSNES et coll 1976)

The aim of the present investigation was to compare two different triiodinated water soluble contrast media with regard to side effects reflected in an increase in serum amylase concentration following injection into the pancreatic duct in the pig The constrast media were the ionic Isopaque (sodium–calcium–magnesium–metrizoate) and the non ionic Amipaque (metrizamide) Amipaque was used as an isotonic solution containing 170 mg I/ml and Isopaque 260 was diluted to the same iodine concentration

Methods

Nine pigs with an average weight of 22 kg (17–35 kg) were used They were fasting for 12 hours before the experiments A barbiturate (Nembutal Veterinary) was given intraperitoneally as an anaesthetic in a dose of 25 mg per kg body weight and anaesthesia was maintained with the same drug intravenously

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Laparatomy was performed after a midline incision and the duodenum was opened at the expected site of the orifice of the pancreatic duct A thin catheter was inserted 1 cm into the duct and sutured to the duodenum A compress was placed in the upper part of the duodenum to prevent contamination of bile (The common bile duct and pancreatic duct have separate outlets into the duodenum in the pig) During the operation 1 000 ml physiologic saline were infused into an ear vein

Four pigs were given Isopaque and 5 Amipaque The injection in the pancreatic duct was performed by hand under fluoroscopy It was intended to obtain as good an acinous filling as possible and the injection was terminated when the contrast medium entered the duodenum Films were then exposed At radiography it is difficult to distinguish acinous from parenchymal filling The term acinous filling is therefore used as it is morphologically easy to comprehend

Blood samples were drawn just after the animals had been anaesthetized before injection of the contrast medium and 1 4 24 and 48 hours following the injection The blood samples were analysed for serum amylase gamma GT sodium potassium chloride and calcium The animals were killed after 48 hours and the pancreas inspected

Results

The condition of the pigs was unaffected when they were killed 48 hours after the laparatomy and retrograde pancreatography On gross inspection the appearance of the pancreas was normal in all pigs without evidence of pancreatitis All blood values except the serum amylase were within normal limits

The serum amylase was increased in all 5 pigs at one hour and 4 hours after injection of Amipaque At 48 hours the values were normalized in 3 pigs but remained high in 2 pigs (Fig 1) Following the injection of Isopaque the serum amylase increased in 3 of the 4 pigs at one hour and 4 hours to the level as after Amipaque injection In 2 of these 3 pigs the value had returned to normal at 48 hours the values from the third pig were unavailable because of technical failures The values at one and 4 hours of the fourth pig injected with Isopaque were also unavailable the one at 48 hours was normal (Fig 2)

No obvious differences between the two groups with regard to the degree of increase of the serum amylase was found No values indicating pancreatitis were recorded

Acinous filling of varying degree was obtained both with Amipaque and Isopaque without evident differences between the two groups

The material was small and the observation period was of short duration Chronic changes in the pancreas caused by the contrast media are thus not possible to estimate

It seems justified to use either Amipaque or Isopaque in the pancreatic duct in man which has initiated their use in clinical work

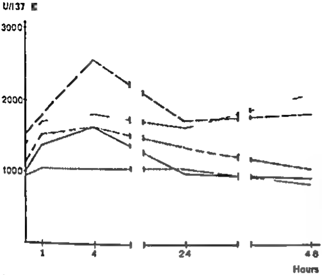

Fig. 1 Serum amylase after injection of Amipaque 170 mg I/ml in the pancreatic duct Normal values 130 to 1 700 U/l 22 to 28 μkat/l

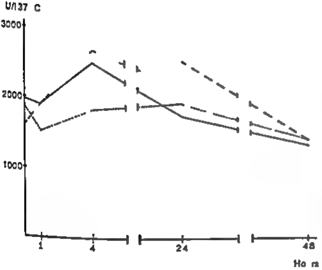

Fig 2 Serum amylase after injection of Isopaque 170 mg I/ml in the pancreatic duct Normal values 130 to 1 700 U/l 22 to 28 μkat/l

SUMMARY

Retrograde pancreatography was performed with Isopaque and Amipaque in pigs The level of amylase in serum during the first two days after the contrast injection was determined No significant difference in the increase of the amylase was recorded

ZUSAMMENFASSUNG

Eine retrograde Pankreatographie mit Isopaque und Amipaque wurde bei Schweinen vorgenommen Die Konzentration an Amylase im Serum wahrend den ersten zwei Tagen nach der Kontrastinjektion wurde untersucht Keine signifikanten Unterschiede im Anstieg der Amylase wurden festgestellt

RESUME

Une pancréatographie retrograde a été exécutée avec l Isopaque et avec l Amipaque sur des porcs Les auteurs ont détermine le taux de l amylase dans le serum pendant les deux premiers jours apres l injection de contraste Ils n ont pas constaté de différence significative dans l elevation de l amylase

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ANGIOGRAPHY OF THE TESTICULAR ARTERY

III Testis and epididymis analysed with a magnification technique

M KORMANO and L NORDMARK

Despite an extensive literature on the vascularization of the male gonad (cf SETCHELL 1970) radiologic application of this knowledge has been insignificant almost non existent Few testicular angiographies of normal adults have been performed (KAHN & FRATES 1968) Such examinations have been so infrequent that the assessment of the potential of testicular angiography as a diagnostic method has not been possible The magnification technique or other measures to improve resolution have not been used nor have definitions been worked out or variations of the normal testicular appearance at angiography established

A standard technique for testicular angiography was recently developed (NORDMARK 1977) By careful analysis of the material available an attempt was made to define what may be considered the normal testicular angiography Such data should prove useful in the evaluation of the complex angiographic appearances of the testis and epididymis especially for the diagnosis of abnormalities in the scrotal testis and epididymis

Anatomy and Terminology The anatomic arrangement of the arterial supply to the testis is presented graphically in Fig 1 a Before entering into the testis the testic

Submitted for publication 24 January 1977

RESUMÉ

Une pancreatographie retrograde a été exécutée avec l Isopaque et avec l Amipaque sur des porcs Les auteurs ont déterminé le taux de l amylase dans le sérum pendant les deux premiers jours apres l injection de contraste Ils n ont pas constaté de difference significative dans l elévation de l amylase

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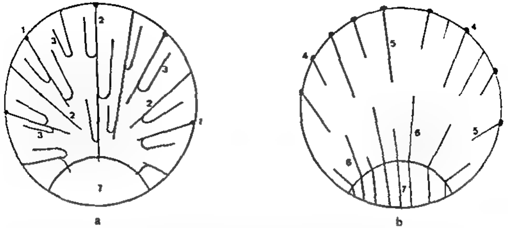

Fig 2. Course of the intratesticular arteries and veins in cross section (Modified from KORMANO & SUORANTA 1971 b) 1 Main branches of the testicular artery (cross sections) 2. Centripetal arteries 3 Centrifugal arteries. 4 Surface veins of the testis (cross sections) 5 Centrifugal veins 6 Centripetal veins 7 Rete testis

... centripetal arteries Many of the major branches of the centripetal arteries run in an opposite direction and are called centrifugal arteries (Fig 2 a) Intratesticular collecting veins are directed towards the rete testis and are called centripetal veins Several veins in the periphery have an opposite course towards the surface of the testis and are called centrifugal veins (Fig 2 b) The surface veins follow the tunica albuginea towards the mediastinum and join there into the centripetal group to form the pampiniform plexus (KORMANO & SUORANTA 1971 b)

Material and Methods

In 29 patients a total of 34 magnification angiographies of the testis were performed at the Department of Diagnostic Radiology University of Umeå between June 1974 and December 1976 Nine of these were considered normal except for extra testicular calcifications phleboliths etc at operation however one small benign extratesticular adenomatous tumour nodule one small spermatocele and one capsular adhesion were revealed In the rest the angiographic result was considered satisfactorily certain and no operation was performed In addition 8 cases of hydrocele all of which had normal testes and epididymes at operation were analysed for intra testicular blood vessels

The technique of testicular angiography was previously described in detail (NORDMARK) The demonstration and the appearances of the arterial and venous vessels in the testis epididymis and in their immediate vicinity were recorded and analysed both in original and subtraction films Circulation times were estimated whenever possible

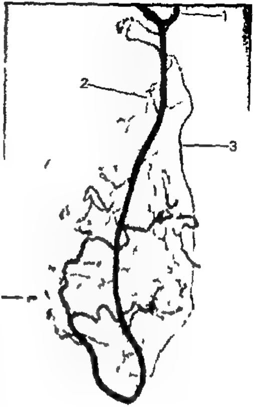

Fig 3 Subtracted magnification Arterial phase 71 year old man with a small tumour like nodule in the left testis Angiography Benign calcified nodule in extratesticular layers (arrow) with no vascular supply The intratesticular arterial branches are heavily coiled a typical finding in elderly men 1 Testicular artery 2 Epididymal arteries 3 Artery to tunica vaginalis runs around the whole testis

Results

In magnification angiography only a short segment of the testicular artery above the testis was demonstrated The degree of coiling of the artery varied widely in some instances it was completely straight No relation between coiling and the size of the testis or other known parameters was observed The epididymal arteries were usually heavily coiled and branched their angiographic demonstration often remaining unsatisfactory The branch which supplies the tunica vaginalis was usually superimposed on the testicular vessels (Fig 3) Despite variation in the number of trunks supplying the testis and in the degree of coiling the main branches of the testis were synchronously demonstrated

The intratesticular vasculature The intratesticular blood vessels were invariably demonstrated up to the centripetal and even the centrifugal arteries (Fig 4) The central venous drainage towards the rete as well as the drainage into the peripheral superficial veins were well demonstrated The uptake of contrast medium in the parenchyma of the normal testis with full spermatogenesis was relatively poor Individual variation in the degree of coiling or spiralling in the centripetal arteries

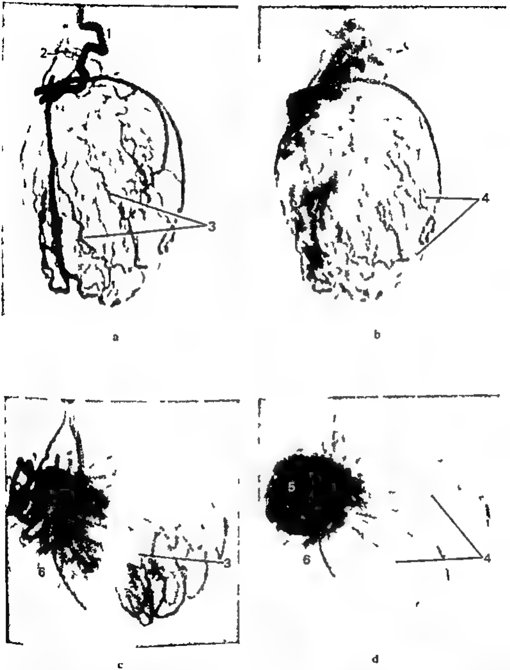

Fig 4 Subtracted magnification a b) A p and c d) axial views of a normal testis a c) Arterial and b d) early venous phases In the a p view the epididymis is located behind the testis In the axial view the small arteries of the head of the epididymis are heavily coiled 1 Testicular artery 2 Epididymal arteries 3 Centripetal arteries inside the testis 4 Surface veins of the testis 5 Pampiniform plexus 6 Epididymal head

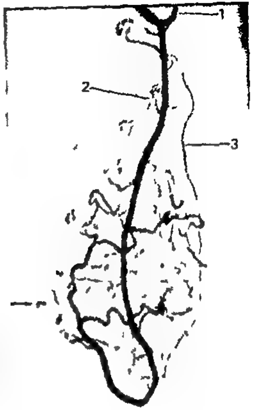

Fig. 3. Subtra[illegible] Arterial phase. 71 year-old man [illegible] mall tumour like nodule in the l[illegible] [illegible]giography. Benign calcified nodul[illegible] [illegible]ular layers (arrow) with no vascular s[illegible]p[illegible]. The intratesticular arterial branches [illegible] h[illegible]avily coiled, a typical finding in eld[illegible]rly [illegible]. 1. Testicular artery. 2. Epididymal arteries. 3. Artery to tunica vaginalis runs around the whole testis.

Results

In magnification angiography only a short segment of the testicular artery above the testis was demonstrated. The degree of coiling of the artery varied widely; in some instances it was completely straight. No relation b[e]tween coiling and the size of the testis or other known parameters was observed. The epididymal arteries were usually heavily coiled and branched, their angiographic demonstration often remaining unsatisfactory. The branch which supplies the tunica vaginalis was usually superimposed on the testicular vessels (Fig. 3). Despite variation in the number of trunks supplying the testis and in the degree of coiling, the main branches of the testis were synchronously demonstrated.

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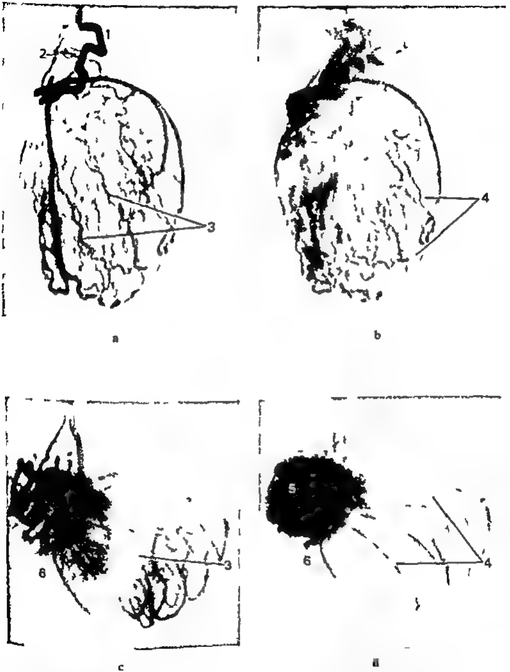

Fig 4 Subtracted magnification a b) A p and c, d) axi l views of a normal testis a c) Arterial and b d) early venous phases In the a p view the epid dymis is located behind the testis In the axial view the small arteries of the head of the epididymis are heavily coiled. 1 Testicular artery 2 Epididymal arteries 3 Centripetal arteries inside the estis 4 Surface veins of the testis 5 Pampini form plexus 6 Epididymal head

was wide spiralling was usually more common in elderly men (Fig 3) The super imposed extratesticular vessels of the tunica vaginalis were sometimes rather con voluted as well even in the absence of intratesticular convolutions and vice versa

The epididymis The visibility of the epididymis in testicular angiography depended on the projection used Due to the activity of the cremasteric muscle a correct position may be impossible to maintain It is difficult to use any substantial traction or pressure as these measures may cause factitious circulatory disturbance

As a rule only the head of the epididymis was fairly well demonstrated in normal cases In the arterial phase the dense vascular network of the head was characteristic In such a case there was also heavy accumulation of contrast medium within the epididymal parenchyma (Fig 5) In most cases no such accumulation occurred in the body and tail of the epididymis and only a few arterial branches were observed

The pampiniform plexus At a normal testicular angiography the pampiniform plexus was the only route of venous drainage The veins were invariably well filled A bundle of slender veins was normally seen Sometimes the venous bundle extended down towards the tail of the epididymis Contrast medium remained in these veins for a long period It was never completely washed out within 30 seconds (Fig 5)

The diameter of the draining veins was easy to determine and early or minimal varicosities were found even when they were not clinically demonstrable (Fig 4) Phleboliths were occasionally present both in the pampiniform and the cremasteric plexuses

Anastomoses In a normal well developed testis filling of the extratesticular arteries was rare except for the branch to the tunica vaginalis and occasional retrograde filling of the deferential artery through its anastomosis along the epididymis (Fig 5) Retrograde filling of the deferential artery was observed only in 2 patients Another major anastomotic connection to the human testis is the cremasteric artery (HARRISON 1949) Such an anastomosis in the arterial phase was not normally demonstrated In the venous phase contrast medium did not normally drain through the cremasteric plexus or other venous anastomoses

Estimated circulation times The circulation of the testis is known to be slow and almost pulseless (WAITES & SETCHELL 1969) Therefore the camera speed was 1 frame every 2 seconds in the arterial phase and 1 frame every 6 seconds in the venous pha e The last view was usually taken 26 seconds after the start of the contrast injection

In a case where the testicular artery arose from the renal artery and was not selectively catheterized it took 15 to 20 seconds for the end of the contrast bolus to move from the origin of the testicular artery into the organ itself If the medium was injected selectively into the testicular artery it took from 3 to 10 seconds ap-

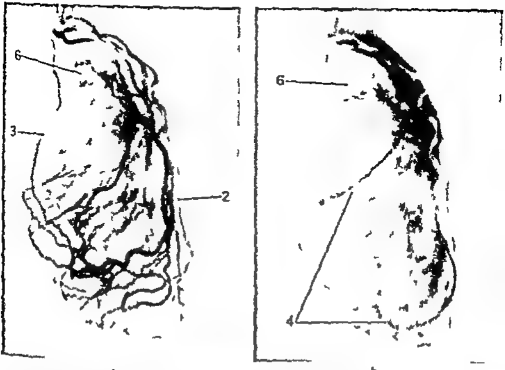

Fig 5 Subtracted magnification Lateral projection a) Arterial and b) venous phases 41 year-old man with a pea sized hard nodule in the right testis Angiography was considered normal Operation revealed a small benign adenoid tumour on the tunica albuginea at the lower pole of the testis, near epididymal tail 1 Testicular artery with four extratesticular divisions 2. Retrograde filling of deferential artery 3 Artery to tunica vaginalis 4 Surface veins of the testis faintly filled 5 Pampiniform plexus 6 Epididymal head

parently due to excessive pressure The catheter was removed from the orifice of the testicular artery immediately after the completed injection to allow a normal flow Yet there was always some contrast medium left in the superficial veins of the testis at 26 to 30 seconds Consequently evaluation of the circulation times through the testis itself was arbitrary usually giving values between 5 and 10 seconds sometimes more There was no apparent difference between the circulation times of the testis and the epididymis

Discussion

The testicular artery has remained outside the scope of angiography despite the fact that almost every artery of the human body has been selectively injected The main reasons for this have been the fear of radiation injury to the testis and the accessibility of the organ for surgical exploration

Provided that relevant information may be obtained from testicular angiography the radiation dose to the gonad should not be a deterrent With the present method

the dose in the testis is of the same magnitude as that in connection with urography without shielding of the testis or a barium enema. This is largely due to the extra-abdominal location of the testis, which allows a well collimated beam and low current.

Another prerequisite for the usefulness of testicular angiography is good resolution and adequate delineation of such anatomic details as can be used for diagnostic purposes. The extra-abdominal location of the testis furthermore provides an excellent opportunity for high resolution angiography with adequate equipment. The unique vascular anatomy of the testis would also seem to give adequate angiographic data for diagnostic purposes. Thus, it seems that displacement of the arteries of the tunica vaginalis or veins from the cremasteric plexus away from the surface veins of the testis serve as a reliable indicator of hydrocele. Accumulation of contrast medium occurs in the parenchyma of a normal epididymal head due to a well developed capillary network (KORMANO & REIJONEN 1976), but in the tail it invariably indicates epididymitis (NORDMARK, to be published). The peculiar course and prolonged filling of the testicular veins facilitates the differentiation of intra- and extratesticular mass lesions. Many of the indications for testicular angiography may be considered relative, but present experience indicates that in some cases decisive information regarding the need for operative intervention may be obtained. Such cases include evaluation of the viability of the testis following scrotal trauma, possible torsion of the testicle, and its differentiation from tumour.

SUMMARY

The resolving capacity of magnification testicular angiography, as related to the known vascular anatomy of the testis and epididymis, was analysed on the basis of 9 normal angiographies and 8 cases of hydrocele with proven normal status of the testis and epididymis. The intratesticular vascular arrangement was demonstrated remarkably well, but of the epididymal vascularity only that in the head of the epididymis. The vascular anatomy of the testis as resolved by angiography may be utilized in the diagnosis of the location and nature of intra- and extratesticular mass lesions.

ZUSAMMENFASSUNG

Die Auflösungskapazität der Vergrösserungs-Angiographie des Testikels im Verhältnis zu der bekannten vaskulären Anatomie des Testikels und der Epididymis wurde auf der Basis von 9 normalen Angiographien und 8 Fällen mit einer Hydrocele mit einem nachgewiesenen normalen Status des Testikels und der Epididymis untersucht. Der intratestikuläre vaskuläre Aufbau stellte sich erstaunlich gut dar, hingegen war die epididymale Vaskularisation nur an der Spitze der Epididymis sichtbar. Die vaskuläre Anatomie des Testikels, wie sie sich bei der Angiographie darstellt, kann zur Diagnose der Lokalisation und der Art von intra- und extratestikulären Läsionen verwendet werden.

RÉSUMÉ

Le pouvoir de résolution de l angiographie testiculaire avec agrandissement compte tenu de l anatomie vasculaire connue du testicule et de l épididyme a été étudié à partir de 9 angiographies normales et de 8 cas d hydrocèle ou il était prouvé que l etat du testicule et de l epididyme etait normal La disposition vasculaire intratesticulaire a été remarquablement bien mise en évidence mais celle de la vascularisation de l epididyme ne l a été bien qu au niveau de la tete de l épididyme L anatomie vasculaire du testicule telle qu elle est detaillée par l angiographie peut etre utilisée pour le diagnostic de siege et de nature de lesion expansive intra et extra testiculaire

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PROTEINURIA FOLLOWING NEPHROANGIOGRAPHY

I Clinical experiences

L TEJLER T ALMÉN and S HOLTÅS

Only few reports on renal failure following nephroangiography with the contrast media in common use today have appeared (STARK & COBURN 1966 SIDD & DECTER 1967 McEVOY et coll 1970 PORT et coll 1974 OLDER et coll 1976) Nephroangiography is now employed even in oliguric patients at some centers with no evidence of further renal injury as long as certain limits with regard to the amount and concentration of contrast medium are respected (KONG et coll 1963 ABRAMS 1971) However recently a massive but transitory proteinuria induced by nephroangiography was observed in two patients at this hospital In one of them the proteinuria was associated with a temporary renal insufficiency This observation initiated an investigation whether transitory proteinuria was common following nephroangiography and the results are now reported

Material and Methods

The material consisted of 34 patients referred during January to March 1975 for nephroangiography from the department of Urology 6 of these were later excluded 5 because of inadequate sampling and one because of a preexisting advanced renal failure The final material thus consisted of 28 patients 14 males and 14 females mean age 61 years range 21 to 84 years The material was divided with respect to glomerular function and angiographic diagnosis into two groups

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Group I (normal kidneys) This was defined as serum creatinine less than 115 μmol/l for men and 100 μmol/l for women urinary albumin less than 0 025 g/g creatinine (upper normal limits for the laboratory) and no abnormalities other than solitary renal cysts or atheromatosis demonstrated at angiography This group comprised 7 individuals (3 males and 4 females) mean age 58 years range 41 to 78 years

Group II (abnormal kidneys but with non glomerular disease) consisted of 21 individuals (11 males and 10 females) mean age 62 years range 21 to 84 years

Angiography Selective nephroangiography was performed in all patients from the femoral artery and in most of the patients also aortography Polyethylene catheters (OD 2 2 mm ID 1 45 mm) were used The following volumes of contrast medium were injected with an automatic pressure injector (Cisal II) aortography 30 ml selective nephroangiography 10 ml or less When a malignant tumor in the kidney was found an additional injection of 30 ml was made into the artery supplying the tumor and furthermore coeliacography and superior mesenteric angiography were performed in a search for liver metastases In 5 patients manual injections of a reduced amount of medium were made into small polar arteries The mean total contrast medium volume used in the patients was 144 ml range 90 to 290 ml The mean total volume injected into one renal artery was 20 ml range 5 to 70 ml In 15 patients Isopaque Coronar was used (Na metrizoate 155 mmol/l meglumine metrizoate 798 mmol/l and Ca metrizoate 8 7 mmol/l with an iodine content of 2 9 mol/l 370 mg I/ml) The mean total volume given was 151 ml range 95 to 290 ml In the remaining 13 patients Isopaque Cerebral was used (meglumine metrizoate 718 mmol/l and Ca metrizoate 8 7 mmol/l with an iodine content of 2 2 mol/l 280 mg I/ml) The mean total volume given in this group was 135 ml range 90 to 260 ml

Sampling and analysis Plasma and urine specimens were obtained before and as soon as possible after the angiography (about ½–4 hours) and on the following first and second day In 6 patients additional specimens were obtained on the sixth or seventh day All samples were frozen and kept at −20 C until analysis Creatinine analysis based on the Jaffe reaction (Jaffe 1886) was carried out by the Technicon method in an Auto Analyzer II (plasma samples) or manually (urine samples) Concentrations of albumin α microglobulin (= RBP retinol binding protein) (Peterson & Berggård 1971) immunoglobulin G and α macroglobulin were determined by immunologic methods using monospecific rabbit antisera Albumin was assayed by automatic immunoprecipitation as described by Lizana & Hellsing (1974) α microglobulin and α macroglobulin by electroimmunoassay (Laurell 1972) and immunoglobulin G by the single radial immunodiffusion method (Mancini et coll 1965) Electrophoresis of unconcentrated urine samples was performed by the method of Johansson (1972) To test the possible influence on the accuracy of the albumin and creatinine assays of the contrast media various amounts were added to aliquots of normal urine (containing about 0 015 g albumin/g creatinine) The final concentrations of contrast medium varied between [illegible] and 50 per cent (v/v) In no instance could any influence on the accuracy of assays be recorded

Results

In 25 of the 28 patients the proteinuria increased markedly following the angio graphy The maximum postangiographic proteinuria varied extremely the concentra tions of albumin being between 0 25 and 160 g/g creatinine

In 9 patients postangiographic urinary albumin concentrations exceeded 10 g/g creatinine Electrophoresis of these samples indicated glomerular proteinuria (cf SCHULTZE & HEREMANS 1966 RENNIE 1971 STROBER & WALDMANN 1974 to which is also referred for general discussions of proteinuria) Maximum proteinuria defined as maximum albuminuria was recorded in the first urine sample obtained after the angiography in 23 patients In the remaining 2 patients reacting with proteinuria this maximum was reached on the day after the angiography The maximum concentra tions of IgG and α microglobulin were found in the samples with maximum albumin concentration with one exception In this case the α_2 microglobulin concentration was higher the day after the maximum albumin concentration was reached

In all patients the proteinuria fell to preangiographic values within 6 days in the majority (19/25) within 2 days In all patients but one belonging to group I this rapid normalization of the proteinuria occurred

No correlation could be demonstrated between the amount of contrast medium and the degree of postangiographic albuminuria This was true regardless whether calcula tions were based on the amount of contrast medium at each injection or the total amount and the postangiographic albuminuria expressed in concentration values or as a factor denoting increase as compared to preexisting albuminuria

When comparing the two contrast media it was found that Isopaque Coronar was associated with higher postangiographic albuminuria than was Isopaque Cerebral (p 0 025 Student s t test) In urine samples reflecting maximum proteinuria signifi cant correlations between concentrations of albumin and IgG and albumin and α_2 microglobulin were found (r = 0 94 and 0 96 respectively) The IgG/albumin clearance ratio (HARDWICKE et coll 1970) was calculated from the concentrations of IgG and albumin in the urine samples demonstrating maximum proteinuria and the correspond ing plasma samples The mean value of this ratio was 0 39 range 0 15 to 0 60

Discussion

The results indicate that transient sometimes massive proteinuria is a common finding following nephroangiography when metrizoate is used as contrast medium in doses generally employed Although there are reports on albuminuria following nephroangiography (IDBOHRN & BERG 1954 IDBOHRN 1956 KIRKLAND 1959 KIRK LAND & HASLOCK 1961) these reports concern iodopyracet and acetrizoate No clinical or experimental report has been found in the literature stating that albuminuria is a common finding following nephroangiography using modern tri iodinated media such as diatrizoate iodamide iothalamate ioxythalamate or metrizoate This is strange

since possible side-effects of nephroangiography have been investigated in man and animal employing these latter media (KONG et coll 1963 GRAINGER et coll 1967 TALNER et coll 1972) At least two explanations why postangiographic proteinuria has escaped notice seem to be possible The proteinuria induced reaches its maximum shortly (within a few hours) following the angiography and is generally of limited duration Its recognition also demands assay systems like the immunochemical ones that are not appreciably influenced by the high concentrations of contrast medium encountered in the early postangiographic urine samples

The observations on massive postangiographic albuminuria referred to in the introduction were made on two patients where glomerular disease could not initially be excluded As glomerular disease might contribute to the postangiographic proteinuria in these patients it was decided to investigate essentially normal or non glomerular diseased kidneys

For valid comparisons of protein excretion in the patients amounts of protein were expressed in relation to urinary creatinine as discussed by HARDWICKE et coll (1970)

The protein assay data demonstrate that the proteinuria induced by the angiography is mainly of glomerular origin as albuminuria of this magnitude could not be caused by inhibition of tubular protein reabsorption only even if this is total (HARDWICKE et coll 1970) Also electrophoresis of urine samples indicated glomerular proteinuria Furthermore the appearance in urine of IgG (mol weight 150 000) generally retained by the glomerular filter (STROBER & WALDMANN 1974) means that there must be an increase in glomerular permeability When relating clearance of IgG to that of albumin it is clear that the glomeruli exhibited some selectivity in filtration of the proteins mentioned (RENNIE 1971 HARDWICKE et coll 1970) In addition α macroglobulin which has a molecular weight of about 725 000 could not be detected in any urine sample Whether angiography besides affecting the glomerular permeability also caused some interference with the tubular reabsorption of proteins could not be determined One of the dominating proteins in tubular proteinuria is α microglobulin (mol weight 21 000) which normally passes through the glomerular filter before it is catabolized in the renal tubular cell (RAVNSKOV 1973) Appreciable amounts of this protein were found in some urine samples As these samples also demonstrated heavy albuminuria the increase in α microglobulin concentration could be explained by an overload of tubular reabsorptive capacity by the glomerular protein leakage (HARDWICKE et coll 1970 RENNIE 1971) and so does not necessarily imply actual injury to tubular cells The decline of the α_2 microglobulin concentration in urine also closely paralleled that of albumin thus supporting the overload theory

The mechanism by which the nephroangiography changes glomerular permeability is not clear However it is known that intravascular injections of contrast media may cause changes in endothelial morphology and vascular permeability (ZINNER & GOTTLOB 1959 BROMAN & OLSSON 1948) It is possible that glomerular capillaries are affected in a similar way Isopaque Coronar produced a higher degree of proteinuria than Isopaque Cerebral and this could be related to one or several factors such as the

higher contrast medium concentration the higher sodium concentration or the higher osmolality of Isopaque Coronar

The frequency and magnitude of the proteinuria was not significantly higher in the group with abnormal kidneys than in the group with normal kidneys But individual factors among the patients may still play a role because 3 patients did not react with proteinuria

Whatever the causative mechanism of the change in glomerular permeability may be this was not of a permanent nature as evidenced by the rapid and total reversal of the proteinuria The present investigation was initiated by the observation of massive proteinuria following nephroangiography in 2 patients one of whom developed a temporary renal failure In the present series no renal failure occurred among the 25 patients reacting with proteinuria and it is unclear whether the proteinuria has any etiologic relation to the renal failures described in some patients following nephro angiography Possibly a high concentration of protein in tubular urine could lead to precipitates blocking the renal tubuli

Postangiographic proteinuria is not exclusively associated with the contrast medium Isopaque (metrizoate) In experiments in dogs (HOLTÅS et coll , to be published) the same degree of proteinuria was found after nephroangiography with Isopaque (metrizoate) as with Urografin (diatrizoate)

Ideally a diagnostic procedure should not even temporarily affect glomerular per meability Therefore an attempt to decrease the effect on the glomerular permeability is intended by changing the composition of the contrast medium solutions

Data on each patient may be obtained from the Department of Diagnostic Radiology Malmo Allmanna Sjukhus S 214 01 Malmo Sweden

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SUMMARY

Following nephroangiography with an ionic contrast medium (metrizoate) proteinuria occurred in 25 of 28 patients reaching its maximum within ½ to 24 hours It fell to preangio graphic values within 5 days The degree of proteinuria varied but was massive i e more than 10 g albumin/g creatinine in 9 patients The underlying mechanism is a marked reversible increase in glomerular permeability

ZUSAMMENFASSUNG

Im Anschluss an eine Nephroangiographie mit einem ionisierten Kontrastmittel (Metri zoat) trat bei 25 von 28 Patienten Proteinurie auf die ihr Maximum innerhalb von 1/2 bis

24 Stunden erreichte Sie fiel auf preangiographische Werte innerhalb von 6 Tagen Der Grad der Proteinurie variierte war jedoch massiv d h mehr als 10 g Albumin/g Creatinin bei 9 Patienten D r zu Grunde liegende Mechanismus ist eine ausgepragte reversible Steigerung der glomerularen Permeabilitat

RÉSUMÉ

Une proteinurie atteignant son maximum entre une demi heure et 24 heures est apparue chez 25 malades sur 28 après néphro-angiographie avec un moyen de contraste ionique (metrizoate) Le taux de proteinurie est revenu à sa valeur pre angiographique en 6 jours Le degre de proteinurie a été variable mais massif c est à dire supérieur à 10 g d albumine par g de creatinine chez 9 malades Le mécanisme sous jacent est une augmentation marquée et réversible de la perméabilité glomérulaire

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TRANSCATHETER ARTERIAL EMBOLIZATION OF NORMAL LIVERS AND EXPERIMENTAL HEPATIC TUMOURS IN THE RAT

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Primary as well as secondary malignant hepatic neoplasms receive their main blood supply from the hepatic artery (BREEDIS & YOUNG 1954). Experimentally as well as clinically it has been demonstrated that ligation of the hepatic artery is followed by necrosis of tumour tissue (NILSSON & ZETTERGREN 1967, ALMERSJÖ et coll. 1972). However, collateral circulation promptly develops following hepatic artery ligation (BENGMARK & ROSENGREN 1970, WIRTANEN & KAUDE 1973) and thus reduces the effect. In order to find out if necrosis of tumour tissue may also be induced by hepatic artery embolization and to what extent this procedure might injure normal liver parenchyma the present investigation was carried out using the rat as an experimental model.

Material and Methods

Rats of the Wistar strain with a weight of about 200 g at the beginning of the experiment were used. The technique for transfemoral selective catheterization of the coeliac artery in the rat has been described previously (EKELUND & OLIN 1970). Occasionally it was also possible to catheterize the hepatic artery. Ether anaesthesia was employed and a small film changer for industrial film (ANGANTYR & OLIN 1973) was used for the angiography with a series of 1 film/s for 6 s (FFD 45 cm, focus 1.0 mm. Film: Agfa Gevaert D4, no intensifying screens. Exposure data: 80 kV, 20 mAs, 0.04 s). For the coeliac artery 0.3 to 0.5 ml of Isopaque Cerebral (Nyegaard, Norway) injected by hand was used and 0.2 to 0.3 ml for the hepatic artery. Fol-

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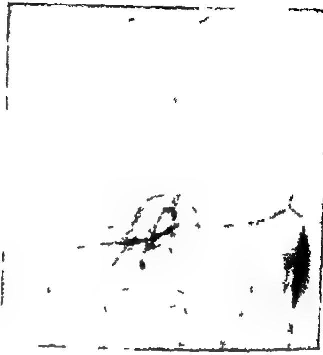


Fig 1 Coeliac angiography (lateral projection) 0 min following ligation of the hepatic artery The hepatic artery with branches is filled indicating collaterals

lowing a primary angiography (in the lateral projection) 0 04 to 0 08 ml of a dispension of 1 mg Spongostan powder (99 3 % gelatin Ferrosan International Denmark) in 4 ml of contrast medium was injected into the coeliac or hepatic artery under fluoroscopy immediately followed by a flush of saline to prevent occlusion of the catheter Five min later repeat angiography was performed usually followed by another angiography 45 to 60 min later After these procedures the catheter was withdrawn and the femoral artery ligated

In 19 normal rats Spongostan was injected in the coeliac or hepatic artery Eight rats died within 12 to 48 hours following embolization Most of these rats had not received any prophylactic antibiotic therapy In the later half of the series antibiotics (penicillin) were routinely administered following embolization with improved survival rates Repeat angiography was performed in 11 normal rats at different time intervals following embolization (1 to 8 days) The second catheterization was performed via the contralateral femoral artery the third from the left carotid artery and eventually a fourth catheterization from the right carotid artery

Eleven rats were examined by angiography 14 to 22 days after intraportal injection with 10^5 to 10^6 living cells of a syngenic colon adenocarcinoma induced with N methyl N' nitro-N nitrosoguanidine (STEELE & SJÖGREN 1974) After subsequent embolization with Spongostan two rats were re examined after 5 and 10 days respectively Eight rats died within 4 days following embolization One rat was kept as a control and not subjected to embolization Angiography was performed 14 and 21 days following tumour cell inoculation in this particular animal

a

b

c

Fig. 2. a) Primary angiography. b) 30 min following embolization. Occlusion of hepatic as well as gastroduodenal artery. c) 5 days later. Catheterization from left carotid artery. Hepatic artery still partly occluded peripherally.

The same procedures were performed in 3 rats with hepatic tumours induced by intraportal inoculation with 10^6 living sarcoma cells of a syngenic polyoma virus-induced kidney sarcoma PW 13 (BANSAL et coll. 1972). At the end of the experiments the still surviving rats were killed and autopsy performed. Sections were prepared from normal as well as tumour livers and stained with hematoxylin erythrosin and according to van Gieson.

Results

The hepatic artery was ligated near its origin in one normal rat. Thirty min after ligation angiography of the coeliac artery was performed demonstrating faint con

a b

Fig. 3. a) Coeliac angiography 14 days following intraportal inoculation with 10^6 living cells from a colon carcinoma. Multiple small tumours peripherally. b) 45 min following peripheral embolization. No contrast medium reaches tumours. Inferior phrenic artery filled and contrast medium refluxed into aorta and superior mesenteric artery.

trast filling of the hepatic artery and its tributaries indicating collateralization (Fig. 1).

Repeat angiography was performed in 11 normal rats 1 to 8 days following embolization with Spongostan. In two rats complete recanalization of the hepatic artery was found after 6 and 8 days, respectively. In 9 rats persistent occlusion to a varying degree could be demonstrated at angiography 1 to 8 days following embolization (Fig. 2). It thus appears that embolic occlusion by means of Spongostan powder lasts for a minimum of 1 to 8 days in most rats.

Microscopy of the liver of one rat (2 hours after Spongostan injection) showed that the main portal veins were moderately dilated while the sinusoids and central veins of the lobules were slightly dilated. In another rat (4 days after injection) these changes were more evident with a marked distension of the portal veins. In 2 other rats (examined 5 and 6 days, respectively, after injection) the changes were again somewhat less marked. No necrosis of liver tissue was observed. All these rats had a persistent total or partial occlusion of the hepatic artery at angiography.

Angiography was performed in 11 rats with liver tumours induced by intraportal inoculation of living cells from a colon carcinoma. The vascularization of these tumours varied somewhat at angiography, but abnormal vessels were always demonstrated and so was often pooling of contrast medium in vascular lakes. Tumour nodules with an avascular center and a hypervascularized surrounding rim were sometimes observed, similar to certain human liver metastases. At angiography following embolization with Spongostan it could be demonstrated that no contrast

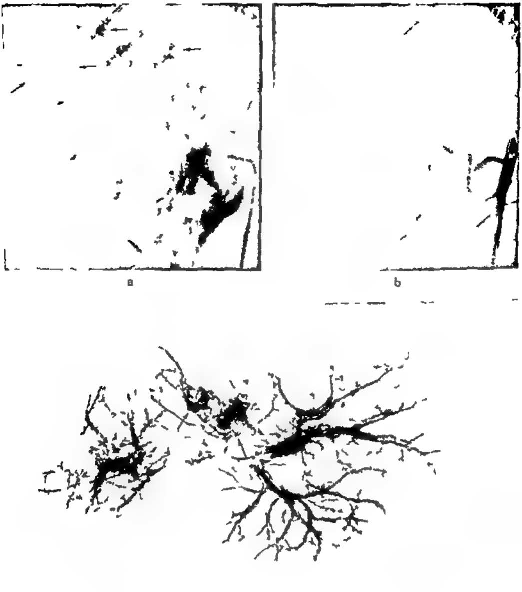
a

b

c

Fig 4 a) Coeliac angiography 21 days following intraportal inoculation with 10^6 colon carcinoma cells. Large liver and abundant tortuous tumour vessels b) 5 min following embolization Embolic material in main hepatic artery (→) Markedly reduced tumour vascularization c) 60 min following embolization Central propagation of occlusion No contrast medium reaches tumour

medium reached the neoplasms (Figs 3 4) Eight rats died within 4 days following embolization and thus no repeat angiography could be performed In one animal multiple tumour nodules with a diameter up to 5 mm were found at angiography After embolization the hepatic as well as the gastroduodenal arteries were occluded Five days later the liver had increased considerably in size as estimated from palpation but unfortunately the rat died during the second catheterization procedure and therefore no angiography could be performed in vivo However barium mixture was injected intraarterially and films of the removed liver exposed The hepatic artery



a b

c

Fig 5 a) Coeliac angiography (late phase lateral projection) 14 days following intraportal inoculation with 10⁶ colon carcinoma cells Multiple small tumour nodules (→) b) After embolization the hepatic as well as the gastroduodenal artery are occluded c) 5 days later Angiography of liver specimen Hepatic arteries again open Three small areas with neovascularity (→)

was again open but only three smaller areas with neovascularity could be demonstrated (Fig 5) Macroscopically multiple tumour nodules appeared on the liver surface of this animal In another rat repeat angiography 10 days following embolization demonstrated recanalization of the hepatic artery and some increase in size of several poorly vascularized hepatic tumours

a b

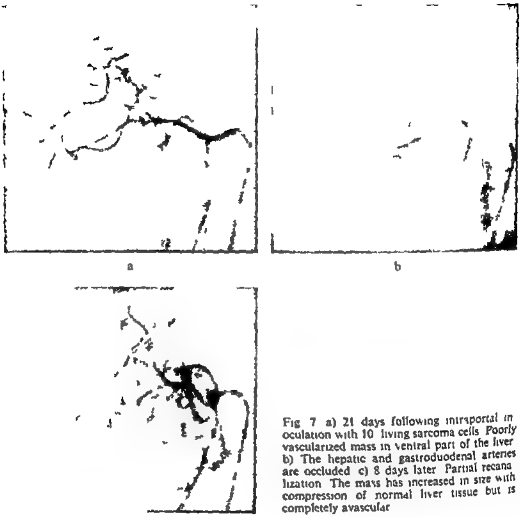
Fig 6 a) 14 days following intraportal inoculation with 10⁶ carcinoma cells Pooling of contrast medium in one small tumour in cranial part of the liver No embolization b) One week later The liver has increased in size and multiple areas with neovascularity are evident Hepatic artery wider than at previous examination indicating increased flow

One rat with hepatic tumours induced by intraportal inoculation with 10^6 colon carcinoma cells was kept as a control Angiography 14 days after inoculation demonstrated pooling of contrast medium in one small tumour No embolization was carried out One week later repeat angiography demonstrated remarkable increase in liver size and multiple areas with tumour vascularity (Fig 6)

Three rats with liver tumours induced by intraportal inoculation with sarcoma cells were subjected to embolization In one of these animals a poorly vascularized hepatic mass was found at angiography After embolization the hepatic artery was totally occluded As could be demonstrated 2 days later at repeat angiography the hepatic artery was partly recanalized and the mass had increased considerably in size but was completely avascular (Fig 7)

In one rat with colonic adenocarcinoma deposits microscopically examined 5 days after Spongostan injection the larger tumour infiltrates contained extensive necroses sometimes without any demonstrable remaining vital tumour tissue sometimes with a narrow peripheral rim of vital tumour tissue Smaller tumour deposits had only small central necroses and consisted mainly of vital tumour tissue The liver tissue also contained fresh coagulation necroses of varying degree especially in strands of liver tissue intervening between tumour deposits In one rat examined 10 days after Spongostan injection the necroses of tumour deposits were less marked with comparatively more vital tumour tissue Also in this animal small necroses in normal liver tissue were apparent

In the control rat (not subjected to embolization) necroses in tumour nodules were also evident although less extensive than in the experimental rat 5 days after Spongostan injection and many tumour nodules consisted of completely vital tumour tissue No necroses appeared in normal liver tissue



a

b

c

Fig. 7. a) 21 days following intraportal inoculation with 10 living sarcoma cells. Poorly vascularized mass in ventral part of the liver. b) The hepatic and gastroduodenal arteries are occluded. c) 8 days later. Partial recanalization. The mass has increased in size with compression of normal liver tissue but is completely avascular.

In one rat with sarcoma deposits examined 2 days after Spongostan injection tumour nodules were nearly totally necrotic with only sparse vital cells in the periphery. On examination of another rat 3 days after injection small satellite nodules of vital tumour were present in the periphery of the large necrotic nodules. In both animals normal liver tissue showed fairly extensive necrosis.

Discussion

Transcatheter selective arterial embolization has recently been introduced in the management of gastrointestinal bleeding and bleeding in the tumour patient (Rösch et coll. 1972, Goldstein et coll. 1975). Embolic occlusion of renal carcinoma with autologous muscle tissue and gelfoam has been tried preoperatively in order to

decrease blood loss during surgery and for palliation of symptoms such as flank pain or hematuria (ALMGÅRD et coll 1973 GOLDSTEIN et coll 1975)

In 1967 NILSSON & ZETTERGREN reported that ligation of the hepatic artery resulted in necrosis of induced liver carcinoma in rats Tumour necrosis has also been reported following hepatic dearterialization in man even if no effect with regard to survival was obtained (ALMERSJÖ et coll 1972) The effect of dearterialization is based upon the fact that hepatic tumours receive their main blood supply from the hepatic artery which has been demonstrated in animals as well as in man (BREEDIS & YOUNG 1954 NILSSON & ZETTERGREN 1967) It is also well known that ligation of the hepatic artery in man is promptly followed by the development of collateral circulation e g from the inferior phrenic artery with ensuing resupply of the liver (BENGMARK & ROSENGREN 1970 WIRTANEN & KAUDE 1973) This was also demonstrated in one of the present rats that had been exposed to ligation of the hepatic artery Previously a technique for catheterization of arteries in the rats was developed (EKELUND & OLIN 1970) which has proved suitable for the angiography of experimental hepatic tumours (EKELUND et coll 1974) Thus it was found natural to apply the trans catheter embolization technique with rats as an experimental model By establishing a more peripheral occlusion of the hepatic artery the risk of collateralization might be reduced When comparing the angiograms of the rat with ligated hepatic artery and those of the rats subjected to embolization it was evident that collateral blood flow had been reduced in the latter group From the experiments with normal rats it was also shown that vascular occlusion with Spongostan powder (99 3 ° gelatin— thus similar to gelfoam) has a temporary effect usually lasting for at least 1 to 8 days The hepatic arterial circulation is then again restituted which perhaps is of clinical importance as the risk of injury to the normal liver is reduced This means that embolization may be repeated at different time intervals

Microscopy has confirmed that the portal circulation is sufficiently effective to prevent serious ischemic injury of the normal liver after hepatic artery occlusion Even if the tumour material is small angiography clearly demonstrated that feeding of the tumours from the hepatic artery was initially arrested by embolization Microscopy of some of these livers revealed extensive tumour necroses with small vital tumour residues Rather wide spread obviously spontaneous necroses were however also evident in the rat kept as control The microscopy also indicates a rather rapid appearance of small vital satellite nodules in the periphery of largely necrotic nodules Obviously it is impossible to draw any conclusions from this small material upon the effect of Spongostan embolization but the results could indicate that the procedure might be of value for inducing tumour necrosis One drawback with the method is indicated by the microscopic findings viz the apparently greater sensitivity to anoxic injury of preserved liver tissue in tumour infiltrated livers Further experiments with larger series and control groups are necessary to evaluate the value and dis advantages of the method

Another drawback with this experimental model is the high mortality resulting

from embolization of the coeliac artery It was found that in the fatal cases extensive embolization of the gastroduodenal artery had also occurred leading to bowel necrosis This is due to technical difficulties to catheterize selectively the hepatic artery in the rat which is only occasionally possible Most of the fatal cases also occurred before prophylactic antibiotic treatment was given as a routine following embolization These technical catheterization difficulties do not exist in man where a selective catheterization of the hepatic artery is quite possible in most cases This suggests that transcatheter embolization in selected cases may be an alternative procedure to hepatic artery ligation thus saving the patient from laparotomy As demonstrated clinically hepatic dearterialization as a sole procedure is not enough to control tumour growth within the liver (ALMERSJÖ et coll 1972) and this is probably the case also with embolization Therefore further experiments with the present model in combination with cytotoxic drugs and immunologic manipulations are necessary in order to evaluate the potential value of transcatheter arterial embolization of hepatic neoplasms

SUMMARY

Transcatheter hepatic arterial embolization with Spongostan (99 3% gelatin) was performed in a group of normal rats By repeat angiography could be demonstrated that arterial occlusions lasted for at least 1 to 8 days in most rats Microscopy of these normal livers gave no evidence of parenchymatous liver injury At postembolization angiography in a group of rats with experimental liver tumours it could be demonstrated that arterial supply of these tumours was temporarily completely arrested Microscopy of some of these neoplasms revealed extensive necroses The eventual future clinical applications of this procedure as an alternative to hepatic artery ligation is discussed

ZUSAMMENFASSUNG

Bei einer Gruppe von Ratten wurde eine Embolisierung der Leberarterie mit Spongostan (99 3% Gelatine) durch ein Katheter durchgefuhrt Durch wiederholte Angiographie konnte nachgewiesen werden dass die Arterienverschlusse wenigstens 1 bis 8 Tagen bei den meisten Ratten anhielten Die Mikroskopie dieser normalen Lebern gab keinen Anhalt fur eine parenchymatose Leberschadigung Bei der Angiographie im Anschluss an eine Embolisierung bei einer Gruppe von Ratten mit experimentellen Lebertumoren konnte gezeigt werden dass die arterielle Versorgung dieser Tumoren zeitweise vollstandig unterbrochen war Die Mikroskopie einiger dieser Tumoren liess eine umfassende Nekrose erkennen Die mogliche zukunftige klinische Anwendung dieses Verfahrens um die Unterbindung der Arteria hepatica zu ersatzen wird diskutiert

RESUME

Une embolisation de l artère hépatique par catheter avec Spongostan (99 3% de gélatine) a eté effectuée sur un groupe de rats normaux Des angiographies répetées ont montré que les occlusions artérielles durent au moins de 1 à 8 jours chez la plupart des rats L examen microscopique de ces foies normaux n a pas montré de signes de lésion du parenchyme hépatique L angiographie après embolisation sur un groupe de rats ayant des tumeurs

hépatiques expérimentales a montré que la vascularisation arterielle de ces tumeurs est temporairement completement arrêtée L examen microscopique de certains de ces neo plasmes a montré des nécroses étendues Les auteurs examinent les applications cliniques futures eventuelles de cette technique pour remplacer la ligature de l artère hépatique

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ANGIOGRAPHY OF CYSTIC LIVER DISEASE

A report of three cases

L DOMELLÖF G F SALTZMAN and O SUNNEGÅRDH

Nonparasitic liver cysts are not uncommon As they relatively seldom give rise to symptoms most of them are detected in connection with laparotomy or autopsy Radiologic procedures have not hitherto been of any particular significance for the diagnosis Calcium deposits in the cyst wall may sometimes be demonstrated but they are much rarer in these cysts than in parasitic liver cysts (SVOBODA 1957) Angio graphy in the form of abdominal aortography (CAPLAN & SIMON 1966 PELTOKALLIO 1970) selective angiography (PELTOKALLIO COUTSOFTIDES & HERMANN 1974) or splenoportal phlebography (KUMMERLE & EHLERT 1967 PELTOKALLIO) has in some cases been successful in demonstrating liver cysts as poorly vascularized expanding lesions Animal experiments (EKELUND et coll 1974) have also indicated that vascular displacement around avascular expansivities is the most common angiographic finding in liver cysts NEIMANN & GOLDSTEIN (1975) recently pointed out that in ad dition to stretching and displacement of hepatic artery branches cysts may appear as sharply circumscribed defects in the hepatographic phase The cysts may be sur rounded by a hypervascular rim representing the cyst wall or adjacent compressed parenchyma It has been considered of interest to present a further three cases of nonparasitic cystic liver disease in which angiography was performed Another reason for reporting them is that the findings in two of the cases support the ob servations made by the last mentioned authors

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Fig 1

Fig 2

Fig 1 Case 1 Capillary phase Strands of liver parenchyma with normal uptake of contrast medium between round avascular areas

Fig 2 Case 2 Arterial phase The intrahepatic arteries stretched and partly curved around expanding lesions

Case reports

Case 1 Female aged 57 At cholecystectomy for a solitary calculus in the gallbladder performed 2 years before the present examination the liver was regarded as normal Following that operation the patient had complained of increasing fatigue intermittent pain in the right hypochondrium and an epigastric sensation of fullness Cholegraphy urography and barium enema revealed nothing abnormal The liver gradually became palpable under the right costal margin Isotope scanning demonstrated hepatomegaly and a well demarcated expanding lesion with a decreased uptake in the upper lateral part of the right liver lobe Routine hematologic and liver tests were normal

Angiography of the hepatic artery (Fig 1) The liver appeared enlarged The intrahepatic vessels were stretched in places displaced around poorly vascularized expanding areas of varying sizes Between these areas strands of liver parenchyma displaying uptake of contrast medium were observed in the capillary phase

Numerous cysts of varying sizes were found at laparotomy The largest of these was evacuated yielding 2 000 ml of thick brownish fluid and was drained over a period of 2 weeks Biopsy of the liver revealed that the liver parenchyma between the cysts was slightly

Fig 3 Case 3 a) Arterial phase b) capillary phase The arteries are stretched and to some extent displaced in the enlarged liver Numerous avascular areas surrounded by liver parenchyma with normal uptake of contrast medium

fibrotic and contained inflammatory cells but was otherwise normal Nothing suggested malignancy After the operation the patient was free from symptoms

Case 2 Male aged 42 Massive heredity for renal cystic disease on the mother s side Hypertonia and polyuria were diagnosed 6 years before the present consultation and urography revealed polycystic renal disease On the same occasion considerable hepatic enlargement was also disclosed on palpation Isotope scanning demonstrated numerous large uptake defects in both liver lobes Six years later the size of the liver had further increased Laparotomy revealed closely packed cysts with no signs of ordinary liver parenchyma The cysts were punctured and yielded 1 500 ml of fluid Samples from the liver displayed little evidence of abnormality A thymol test gave a slightly raised value and a bromsulphalein test was moderately pathologic Renal function was only slightly impaired

Angiography of the coeliac artery (Fig 2) was performed 6 months after the laparotomy and revealed displacement of the blood vessels in an enlarged liver No abnormal vessels were seen and there was no uptake of contrast medium in the renal parenchyma The patient has been under observation for a further 4 years and the clinical picture has remained unchanged

Case 3 Female aged 40 Hematuria had been diagnosed 5 years before Urography and nephroangiography were carried out and demonstrated the characteristic appearances of polycystic renal disease Renal function tests in the following 5 years were normal In connection with recent symptoms suggestive of gallstone no contrast filling of the gall bladder was obtained at a peroral cholecystography Liver function tests of various types all gave normal results Scintigraphy revealed an enlarged liver with multiple uptake defects

Angiography of the coeliac and superior mesenteric arteries (Fig 3) The hepatic artery arose as a branch from the superior mesenteric artery and the intrahepatic arterial branches were in some areas displaced In the capillary phase multiple round defects were evident between normally contrast filled liver parenchyma

At laparotomy numerous liver cysts of varying size were found in the enlarged liver The liver capsule was slightly fibrotic The parenchyma between the cysts was macroscopically normal

Discussion

Nonparasitic cystic liver disease has previously been diagnosed mostly at laparotomy Angiography has been considered of some value for diagnosis due to the fact that the vessels have been displaced around the larger cysts

As the liver function, in patients with this disease is usually only slightly or not at all impaired a large part of the liver parenchyma remains intact The functioning parenchyma is demonstrated at radiography through the uptake of contrast medium (Cases 1 3) This is achieved by high quality films produced by applying the highest possible selectivity in the angiographic technique The subtraction method would probably be of value in some cases

The fact that nonparasitic polycystic liver disease is often combined with polycystic renal disea e as was the case both in these three patients and in those previously reported brings up the question of whether the liver should not be examined in all patients in whom polycystic renal disease has been diagnosed The question deserves all the more consideration since it seems likely that angiography could in the future be substituted by computer tomography or ultrasonography which involve less discomfort for the patient

SUMMARY

Three patients wi h nonparasitic polycystic liver disease have been examined by angiography The value and technical aspects of the examination are discussed in the light of the observations in thes cases as well as in previously reported cases

ZUSAMMENFASSUNG

Drei Patienten mit nichtparasitischer polyzystischer Lebererkrankung wurden angiographisch untersucht Der Wert und die technischen Aspekte dieser Untersuchung werden im Lichte von den Beobachtungen bei diesen Fällen so wie bei früher beschriebenen Fäll n diskutiert

RESUME

Trois malades atteints de maladie polykystique du foie non parasitaire ont été examinés par angiographie Les auteurs examinent la valeur et les aspects techniques de cet examen a la lumiere des observations faites dans ces cas ainsi que d apres la littérature

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DIRECT COMMUNICATION BETWEEN A CORONARY ARTERY AND THE RIGHT VENTRICLE

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A number of functional anomalies and malformations of the coronary arteries have been identified at angiography (EDWARDS 1958, BLAKE et coll. 1964, OGDEN & STANSEL 1971, STEINBERG & HOLSWADE 1972). Improved techniques will probably lead to further information on coronary hemodynamics. This report concerns 3 patients with small direct communications between coronary arteries and the right ventricle.

Case reports

Case 1. A 58 year old Caucasian male was admitted with severe precordial pain associated with a recent anterior myocardial infarction. Five months later he was again hospitalized for severe anginal pain. Selective coronary angiography revealed diffuse coronary arteries as well as multiple [illegible]enoses of the left circumflex artery and marginal branches. Collateral flow from the proximal diagonal and marginal branches to the distal left anterior descending artery and right po[s]terior descending arteries was visible. In the midpart of the interventricular septum two [b]ranches of the first septal artery terminated abruptly. From this point a small but contin[u]ous flow of contrast medium into the right ventricular cavity occurred. This direct comm[u]nication between the septal branches [a]nd the right ventricle was clearly identified in both [o]blique and the lateral projections (Fi[g]. 1 a).

At left ventric[u]lar cineangiography hypokinesia of th[e] [illegible] [illegible] walls as well as paradoxical [m]ovement of the apex were revealed [illegible] [illegible] [illegible]ency due

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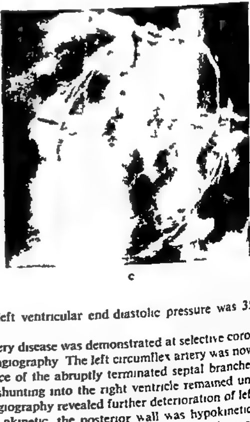
a b



c

Fig 1 Case 1 Left coronary angiography a) Left posterior oblique projection The first septal branch of the left anterior descending artery divides into 2 branches (→) Both terminate abruptly in a small accumulation of contrast medium in the right ventricle (↔) b) Lateral projection 16 months later Additional occlusion of the circumflex artery (⇸) No change in size of the first septal artery (↔) and in appearance of the fistula (↔) c) Left anterior oblique projection Position of coronary artery right ventricular communication fed by the septal artery (→) clearly evident

to papillary dysfunction was evident The left ventricular end diastolic pressure was 35 mm Hg

Significant progression of the coronary artery disease was demonstrated at selective coronary angiography 16 months after the first angiography The left circumflex artery was now occluded (Fig 1 c) The size and appearance of the abruptly terminated septal branches as well as the amount of contrast medium shunting into the right ventricle remained unchanged (Fig 1 b c) Left ventricular cineangiography revealed further deterioration of left ventricular function The anterior wall was akinetic the posterior wall was hypokinetic and paradoxical movements were visible in the apical area A grade 2/4 mitral insufficiency was again apparent It was not possible to document the left to-right shunt by means of oxymetry Dye dilution curves were normal when the dye was injected into the pulmonary

Fig 2 Case 2 Cineangiography Left coronary artery in the right anterior oblique projection A branch of the septal artery communicates directly with pool of contrast medium in the right ventricle (—>)

artery and blood samples were taken from the femoral artery as well as when dye was injected into the aortic root and blood samples were taken from the pulmonary artery However when the dye was injected into the left coronary artery and blood samples were taken from the right ventricle close to the terminal segment of the fistula a left to-right shunt was reflected in an early appearance on the dye dilution curve

Case 2 A 55 year old previously healthy Caucasian female was admitted with a 4-month history of atypical chest pain and type 4 hyperlipidemia

Left ventricular cardioangiography revealed a ventricle of normal size with no evidence of localized wall dysfunction Coronary angiography demonstrated a 75 per cent stenosis in the mid third of the right coronary artery A 20 per cent stenosis in the left anterior descending branch was found The coronary arteries were otherwise normal

From one of the distal septal branches of the left anterior descending artery a small artery (approximately 0 5 mm in diameter) entered the right ventricle and deposited a small pool of contrast medium between the trabeculae alternatingly disappearing in ventricular systole and refilling in diastole (Fig 2) There were no interconnecting capillaries or system of smaller vessels between the artery and the collection of contrast medium

Case 3 A 58 year old male was admitted with a 10-year history of hypertension and chest pain of increasing severity to which shortness of breath had added. ECG 7 to 8 years previously had revealed changes compatible with an old myocardial infarct At that time the patient also was found to have a murmur consistent with moderate aortic stenosis Two months before the examination the patient had an episod^ of syncope

At cardiac catheterization the resting gradient across the aortic valve was 15 mm Hg but no aortic insufficiency was observed The left ventricular end-diastolic pressure was 24 mm Hg

Cardioangiography revealed a moderately dilated left ventricle with an ejection fraction reduced to about 40 per cent A large area of akinesis involved the anterior part of the diaphragmatic wall of the left ventricle

Coronary angiography revealed multiple severe stenoses in all 3 major coronary arteries In addition a small collection of contrast medium was emptied from a small branch of the distal right coronary artery directly into the cavity of the right ventricle between trabeculae The medium was washed away during each ventricular systole

Discussion

The nature of these direct arterial communications of small branches from the left and right coronary arteries into the right cardiac ventricle is obscure Common angiographic features among these patients included feeding vessels of normal size localization of the terminal segment of the fistula in the right ventricle and minimum shunting through the fistula Coronary artery disease was present in all 3 patients All had a history of myocardial infarctions and in 2 patients this was confirmed by ECG and angiography

The directly communicating arteries were structurally different from the other communications between the coronary arteries and the cardiac chambers which involve capillaries and veins such as thebesian veins and arterio sinusoidal vessels (WEARN et coll 1933) It is also clear that the amount of flow through these communications in the present patients was too small to have any significant effect on the function of the heart They are thus clearly different from true coronary artery fistulas (EDWARDS 1958 BLAKE et coll 1964 OGDEN & STANSEL 1971 STEINBERG & HOLSWADE 1972 CHETOCHINE et coll 1973 GROLLMAN et coll 1974 SILVERMAN et coll 1974)

Since the patients all had coronary artery disease the fistulas may have been a result of localized infarct or necrosis of the myocardium with creation of a fistula from the coronary artery branches to the ventricle The low pressure in the right ventricle and the location of the septal arteries near the right ventricular cavity (JAMES & BURCH 1958) make this explanation plausible The vessels feeding such a communication would probably tend to grow however and in one of the patients the fistula remained unchanged over 16 months Also perforation of coronary arteries in infarcts has never been observed at numerous postmortem injections (BAROLDI 1975)

Another possibility is that they are the normal arterial luminal vessels first described by VIEUSSENS (1706) and later demonstrated by dye injections in specimens by WEARN et coll (1933) The three hearts described in detail were from males in their thirties who had died from pneumonia They found an average of 20 to 25 communicating arterial luminal vessels opening into the right and left ventricles Most of them seemed to come from the left anterior descending branch of the left artery and most of them entered the left ventricle Thus the number of communicating arteries in each area

corresponded to the muscular mass and the blood supply The diameter of the arterial communications measured 0 2 to 1 mm

The reasons why these types of communication have not been observed previously in coronary angiography may be several First it is only with the advent of high resolution cesium iodide image intensifiers that routine coronary angiography has achieved the quality that generally would make perception of such small branches more likely Secondly these communications may normally carry such a small amount of flow that their identification by angiography is impossible

It is also possible that their appearance in the patients reported here reflects local contraction disturbances in the left ventricular wall This could lead to alterations in flow which improve demonstration of these pre-existing communications Although minimal the flow of contrast medium into the right ventricular cavity was characteristic and well documented on cineangiography in all 3 cases This image should not be confused with the coronary vascularity seen during occlusion angiography of the coronary artery (SPINDOLA FRANCO et coll 1975)

It is logical to assume that with improved imaging methods additional cases will be recognized and reported Correlation with pathology may establish the etiology of this type of coronary artery to right ventricle communication

SUMMARY

A small direct communication between a coronary artery and the right ventricle was demonstrated angiographically in 3 patients All patients had coronary artery disease and histories of myocardial infarction The possible etiologies of these communications are discussed

ZUSAMMENFASSUNG

Eine kleine direkte Verbindung zwischen einer Koronararterie und dem rechten Ventrikel wurde angiographisch bei 3 Patienten nachgewiesen Alle Patienten hatten Erkrankungen der Koronararterien und die Vorgeschichte eines Herzinfarktes Die mögliche Ätiologie dieser Verbindung n wird diskutiert

RESUME

Les auteurs ont mis en evidence une petite communication directe entre une artère coronaire et le ventricule droit par angiographie chez trois malades Tous ces malades avaient une affection des artères coronaires et des antecedents d infarctus du myocarde Les auteurs examinent les etiologies possibles de ces communications

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DUPLICATION OF THE RENAL COLLECTING SYSTEM WITH HYPOPLASIA OF THE UPPER POLE OF THE KIDNEY

G CAPPELLINI P PAVLICA G STASI and G VIGLIETTA

Duplication of the renal pelvis and ureter is the most frequent anomaly in the urinary tract The superior pelvis is usually smaller than the lower one with one or two major calyces only The corresponding ureter opens out either more caudally in the bladder than the normal one adjacent to the trigone at the neck of the bladder or it may also have its opening in the urethra or the vagina

If only the upper part of the kidney is functioning (which is seldom met with) the abnormal appearance of the upper pelvis reveals that duplication of the collecting system exists but if the part of the parenchyma corresponding to the upper pelvis is non functioning recognition of the condition may be difficult at urography as no evident abnormality of the demonstrated pelvis may be present A conspicuously long distance between the uppermost calyx and the upper pole of the kidney and the small size of the pelvis in relation to the size of the kidney may suggest duplication

KITTREDGE & LEVIN (1973) reported 3 cases of dysplasia of the upper pole of the kidney where a cap like zone of functioning parenchyma surrounded a non functioning region and a hydronephrotic upper pelvis The angiographic appearance was considered likely to lead easily to diagnostic errors and useless surgical intervention

Recently 2 cases of dysplasia of the upper pole with poor function of the parenchyma were observed at this hospital The appearances at urography and angiography were similar in these 2 cases and similar to the 3 cases described by KITTREDGE & LEVIN

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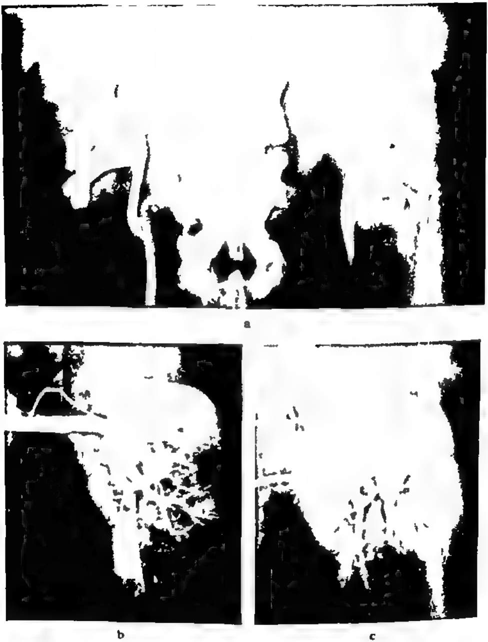

Fig 1 Case 1 a) Urography Tomography The left kidney is shorter than the right the upper pole abnormal with reduced nephrographic effect The upper medial outlining of the pelvis is straight b) Selective angiography a p view The renal artery has a horizontal course a downward directed curve near the kidney From its superior aspect a small artery originates forming a network at the superior pole c) Oblique view The vascularized tip of the pole separated by the non functioning parenchyma more evident and appearing as a cap

a

b

Fig Case 2 a) Urography The left kidney is smaller than the right one The medial superior border of the pelvis straight b) Tomography Irregular upper pole with a cap of functioning parenchyma above a non functioning zone

a b

Fig 3 Case 2 Selective angiography Sinuous course of the renal artery a) From the upper aspect of the renal artery a small branch runs to a vascular network at the upper pole The inferior supra renal artery is also demonstrated b) Irregular nephrographic effect bordering the non functioning parenchyma

The upper part of the kidney appeared wider than the contralateral one Just below the tip of the upper pole a more or less marked irregular constriction was present resulting in a small bulging of the contour upwards medially not evident in one of the cases At urography one pelvis with calyces filled on the abnormal side The upper medial outlining of the pelvis was straight and more vertically directed than usual The distance between the upper calyx and the upper border of the kidney was slightly longer than on the contralateral side but the number of calyces was about the same A faint irregular nephrographic effect occurred at the periphery of the upper pole separated from the rest of the kidney by a narrow zone without evident accumulation of contrast medium (Figs 1 a 2 b)

At angiography the renal artery entered the kidney above its middle and ran in a curve with the concavity downwards before dividing into the main branches A small artery branched off from the main stem to the tip of the superior pole (Figs 1 b 3 a) where an irregular network of small arteries was demonstrated In the nephrographic phase the zone of non functioning parenchyma was better demarcated and the accumulation of the contrast medium in the tip of the upper pole was more evident than at urography thus giving rise to the cap-like appearance described by KITTREDGE & LEVIN The abnormality was most evident on oblique views (Figs 1 c 3 b) One of the patients was operated upon and a duplication of the collecting system was found The upper pelvis was hydronephrotic and the corresponding parenchyma atrophic

Discussion

In duplication the lower pelvis with its calyces has an almost normal appearance but is usually somewhat smaller than the contralateral one The number of calyces

is usually the same on both sides At microscopy developmental disturbances are found in the parenchyma related to the upper pelvis but usually they are not so severe as to influence the outline of the kidney Therefore disregarding a slight increase in length the kidney has an almost normal appearance This means that the distance from the upper outlining of the kidney to the superior calyx is longer than this distance on the contralateral side the pelvis appears to be located more distally than normally in the kidney These features as well as the straight upper medial border of the pelvis and a lateral deviation of the upper calyx indicate that a duplication exists also in cases where the upper pelvis does not fill at urography

Due to the abnormal parenchyma corresponding to the upper pelvis the function of this part of the kidney may be impaired but in most cases only slightly If this part is more severely dysplastic or a pathologic process with destruction or atrophy of the parenchyma has developed this part of the kidney is reduced in volume This explains why the present kidneys as well as those of KITTREDGE & LEVIN had no evident increase in length and why the upper part of the demonstrated kidney appeared wider than usual In the present cases a small artery branched off from the main stem of the renal artery and ran to the upper pole The illustrations in the report of KITTREDGE & LEVIN seem to indicate that the tip of the upper pole was vascularized in a similar way in their cases i e by extrarenal arteries

In the part with no nephrographic effect the intrarenal vessels were few narrow and stretched If only such pathologic arteries pass to the tip of the upper pole the blood flow will be impaired and the nephrographic effect slight or absent In the present case as probably also in the cases of KITTREDGE & LEVIN the parenchyma at the top of the kidney was vascularized by extrarenal arteries and contained an irregular vascular network In this part of the upper pole a more or less irregular nephrographic effect occurred giving rise to the cap-like appearance The vascularized part appeared as a protuberance on the upper part of the kidney directed upwards and medially The extrarenal artery must be distinguished from the inferior suprarenal and the superior renal capsular arteries In all cases observed the renal artery entered the kidney above its middle and described a curve with the concavity downwards The urographic and angiographic appearances seem to be due not only to a dysplasia and atrophy of the upper pole but also to a vascular abnormality An exact diagnosis of the condition seems to be possible and thus the optimum planning of the treatment

SUMMARY

Two cases of pyelo ureteral duplication with dysplasia of the upper pole of the kidney are reported A zone of functioning parenchyma at the tip surrounded a non functioning region The functioning part was vascularized by an extrarenal artery An exact diagnosis of the condition seems to be possible

ZUSAMMENFASSUNG

Zwei Falle einer pyelo-uretaren Verdoppelung mit Dysplasie des oberen Pols der Niere werden beschrieben Eine Zone funktionierenden Parenchyms an der Spitze ist von einer nicht funktionierenden Region umgeben Der funktionierende Teil war durch eine extra renale Arterie vaskularisiert Eine exakte Diagnose dieser Verhaltnisse scheint moglich zu sein

RESUMÉ

Deux cas de duplication pyelo urétérale avec dysplasie du pole superieur du rein sont présentés Une zone de parenchyme fonctionnel au sommet entoure une zone non fonction nelle La partie fonctionnelle est vascularisee par une artere extra rénale le diagnostic exact de cette affection parait possible

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY ÖSTRA SJUKHUSET S 412 24 GOTHENBURG SWEDEN

MULTIPLE CALCULI IN A MECKEL'S DIVERTICULUM

Report of a case

HUGO G BOGREN and LARS BILLING

A Meckel's diverticulum is a blind outpouching of the rudimentary omphalomesenteric duct situated in the ileum 30 to 90 cm proximal to the ileocecal valve. Meckel's diverticula are generally harmless and of no clinical significance but may occasionally be complicated by inflammation, ulceration or hemorrhage or be the cause of intussusception or volvolus. Calculi in a Meckel's diverticulum is probably the most rare complication but have been reported in approximately 30 cases, most of them during the 1950's and 1960's. The symptomatology of the disease is unspecific but the radiologic findings may be diagnostic as illustrated in the following case.

Case report

A 47 year-old female had complained of intermit[illegible] right lower quadrant pain for two years. She had been hospitalized twice because of acute abdominal pain and had been discharged without definitive diagnosis. Urograph[illegible] cholecystography and barium enema had been perform[illegible] outside this institution and h[illegible]n reported as normal.

On survey film[illegible] of the abdomen multiple fa[illegible] calculi of coffee bean size we[illegible] seen in the right low[illegible] quadrant of the abdomen at [illegible] level of the ischial [illegible] The [illegible]lculi looked like bil[illegible] calculi in an atypical locatio[illegible] 1)

On small bow[illegible] examination barium contrast [illegible]dium started to appe[illegible] on one and a half hou[illegible]s after ingestion and after ano[illegible] hour barium filled a [illegible]el diverticulum contai[illegible]ing the calculi (Fig 2)

Submitted fo[illegible] publication 12 April 1977

Fig 1

Fig 2

Fig 1 Detail of survey film of the pelvis Multiple faceted calcifications resembling gallstones in the right mid pelvis at the level of the ischial spine

Fig 2 Detail of small bowel examination 2½ hours after barium contrast medium ingestion The lower part of the Meckel s diverticulum containing calculi is filled with contrast medium

A Meckel s diverticulum 3 cm in diameter widely connected with the ileum was found at surgery a second outpouching from the distal part of the diverticulum contained the calculi

At microscopy small bowel mucosa was found in both parts of the diverticulum but also small islands of gastric mucosa The calculi were greenish gray and could easily be mistaken for gallstones

The stones contained cholesterol bile salts bile pigments calcium carbonate and calcium oxalate No crystalline cholesterol calcium carbonate or calcium oxalate was found at roentgen diffraction examination but lines from a hitherto unidentified crystalline substance

Discussion

The present case report illustrates the clinical difficulties in the diagnosis of this rare entity in a patient who had been hospitalized twice during two years The calculi found on survey abdominal films closely resembled gallstones radiographically but because of their caudal location enteroliths were suggested and a diagnostic small bowel examination was performed The differential diagnosis included biliary calculi stones in an appendix (BRECCIA & CERONE 1968) and possibly also gallstone ileus (CARIDIS & SMITH 1965 SCHLÖGELHOFER 1964) Small bowel examination should be performed in all cases with atypically located gallstone like calculi

The etiology of the calculi in Meckel s diverticula is purely speculative but has been attributed to stasis secondary to inflammation Bile salts are rarely reported in calculi in Meckel s diverticula Calcium oxalate phosphate and carbonate are commonly reported oxalate and carbonate were found also in this case although in a non-crystalline form

SUMMARY

Report of a case of pre operative diagnosis of calculi in a Meckel s diverticulum occurring in a 47 year old female

ZUSAMMENFASSUNG

Bericht uber einen Fall einer pra operativen Diagnose von Steinen in einem Meckelschen Divertikel welches bei einer 47 Jahre alten Frau auftrat

RESUME

Presentation d un cas de diagnostic pre-operatoire de calculs dans un diverticule de Meckel chez une femme agée de 47 ans

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FROM THE DEPARTMENT OF RADIOLOGY (ACTING CHAIRMAN M C BEACHLEY) MEDICAL COLLEGE OF VIRGINIA HOSPITALS RICHMOND VIRGINIA 23298 U S A

SUPERSELECTIVE ARTERIAL EMBOLIZATION FOR THE CONTROL OF POSTSURGICAL BLEEDING

Report of a case

S O HIETALA

Transcatheter selective arterial embolization has been increasingly utilized for the control of non neoplastic gastrointestinal bleeding (GOLD & GRACE 1975 REUTER et coll 1975 ROSCH et coll 1972) and traumatic renal (BOOKSTEIN & GOLDSTEIN 1973) and pelvic hemorrhage (BEN MENACHEM et coll 1975) The same approach has also been used in the treatment of tumors (GOLDSTEIN et coll 1975) and arterio venous malformations The different materials used for embolization include auto logous tissue and clot (MARGOLIS et coll 1972 REUTER & CHUANG 1974 REUTER et coll) blood augmented by thrombin or Amicar (Lederle Inc) (REUTER et coll) Gelfoam (Upjohn Inc) (GOLD & GRACE) metallic or silastic spheres and various mechanical devices (ROSCH et coll)

Recently a case of postsurgical bleeding was observed at this hospital The bleeding site in the thigh was localized angiographically and successfully stopped by Gelfoam embolization This case is now reported

Case report

The patient was a 28 year old male who arrived in the emergency room in shock He was found to have multiple gunshot wounds penetrating the left axillary region and apex of the deltoid region left and right groin left lateral thigh left and right knee and the left

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Fig 1 Shape of the red Kifa catheter (OD 2 [illegible] mm, ID 1 2 mm) used The radius of the curve is 1 5 cm and the length of the distal limb is 4 5 cm Steering bend at the end of the catheter

ankle He had a comminuted intertrochanteric fracture with dislocation of the left hip and also a fracture of the left tibia and fibula and of the right tibial tubercle

The patient was taken to the operating room and both right and left groins were explored No arterial injuries were found The left axillary region was also explored and an arterial tear was detected It was not possible to do an end to-end anastomosis so a vein patch was inserted All the other wounds were debrided and drained

The left leg was kept in traction because of the comminuted and dislocated fracture of the hip The injured skin over the fracture region healed one month after admission at which time surgical reduction and fixation of the hip fracture and dislocation were performed An incision was made through the skin subcutaneous tissue fascia lata and vastus lateralis exposing the shaft of the femur A considerable amount of hemorrhage was encountered from the scar tissue surrounding the fracture The fracture was fixed with Deyerle plates and pins During the operative procedure the blood pressure dropped to 80 mm Hg systolic and remained there for approximately 15 minutes It was restored to 120 mm Hg systolic by the infusion of whole blood

The day following the operation bleeding from the wound was revealed The left thigh was swollen and edematous The hemoglobin was 9 7 gram per cent and the patient was given 2 units (500 ml) of packed red cells Despite the transfusion of an additional 9 units of blood on the second postoperative day his hemoglobin continued to drop and was 7 4 gram per cent The chances of finding the bleeding site by surgical exploration of the edematous leg 2 days after the operation were considered to be minimal Therefore angiography was performed to locate the bleeding site

Angiographic procedure A thin walled pre-shaped red Kifa catheter (OD 2 2 mm ID 1 2 mm Fig 1) was introduced percutaneously through the opposite femoral artery and passed up to the abdominal aorta The pre formed shape of the catheter was regained by placing its tip into a renal artery The catheter was withdrawn so that the tip entered the left common iliac artery and was advanced into the common femoral artery without difficulty by using a teflon coated wide J guidewire with a removable core (Cook) An injection of 25 ml of Renografin 76% was made at the rate of about 8 ml/s The filming sequence was 2 film/s for 4 seconds followed by 1 film/s for an additional 12 seconds This examination did not demonstrate any bleeding site The catheter was then advanced into the superficial femoral artery but no abnormalities were found Selective examination of the deep femoral artery however (Fig 2 a) revealed a definite bleeding point in the lateral thigh The bleeding originated from one of the major muscular branches Early filling of the corresponding veins was also obtained indicating an arteriovenous fistula

The catheter was then passed down through the deep femoral artery into the bleeding arterial

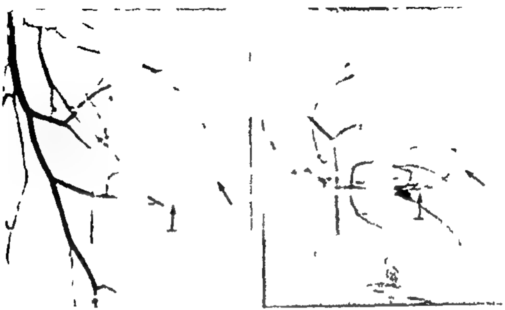

Fig 2. a) Selective examination of the left deep femoral artery before embolization arterial phase Extravasation of contrast medium (→) from an arterial branch to the musculature of the thigh Early venous filling (↔) b) Superselective examination of the bleeding artery before embolization arterial phase Extravasation (→) and early venous filling (↔) more evident

branch and the findings were confirmed (Fig 2 b) Extravasation was also visible fluoroscopically during the injection of the contrast medium The catheter had a stable position in the bleeding artery near the bleeding site and embolization of the vessel by Gelfoam was therefore considered appropriate

Embolization The Gelfoam emboli were cut in strips approximately 1 mm 3 mm 18 mm (Fig. 3) A tuberculin syringe (Plastipak 1 ml) was filled with contrast medium The Gelfoam strips were then rolled and placed in the syringe Fifteen syringes were loaded in this way The embolization was performed under careful fluoroscopic control and the procedure was terminated when the vessel seemed to be totally occluded (Fig 4) Following the injection of the emboli a repeat angiography was performed to observe the completeness of the occlusion The vessel was totally occluded at its origin from the deep femoral artery (Fig 5)

Follow up The left thigh was edematous and painful the day following embolization The patient received a transfusion of one unit (500 ml) of whole blood and his condition progressively improved The thigh was still somewhat edematous but the patient experienced less pain and was resting comfortably His situation was stable 3 days after embolization The hemoglobin was 10 7 gram per cent The patient refused repeat angiography and he was discharged 6 days after embolization in good physical condition

Discussion

This case demonstrates the value of angiography in the management of post traumatic bleeding Such a bleeding site is often not detected at the surgical exploration of the region of a penetrating wound or a previous operation A surgical ligation

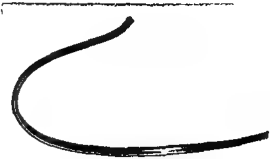

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Fig 4

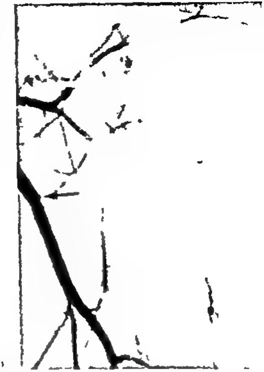

Fig 5

Fig 4 Conventional film Left thigh after embolization The Gelfoam emboli (→) soaked with contrast medium occupy the main stem of the bleeding artery

Fig 5 Selective examination of the left deep femoral artery after embolization arterial phase The bleeding artery is totally occluded at the origin from the deep femoral artery (→)

acid (Amicar) Amicar reacts with plasmin to form a fibrin clot which has an increased resistance to fibrinolysin (REUTER et coll 1975) These Amicar mixed clot emboli resolve within 24 hours (REUTER & CHUANG 1974)

Occlusion lasting from weeks to permanently may be obtained by using absorbable non autogenous materials such as Gelfoam Although Gelfoam is not absorbed for up to 2 weeks animal experiments have shown that it is pushed peripherally and compressed by the arterial pulsation (GOLD & GRACE 1975) Therefore an occluded artery may appear to open and its branches may be filled with contrast medium over a period of 24 hours after embolization A repeat angiography of the patient would therefore have been of interest

The potential complication of injecting any type of embolic material should be considered The emboli may leave the injection site and lodge in arteries other than the intended ones This complication is prevented by positioning the catheter stably as near the bleeding site as possible Other factors that may contribute to misplaced emboli are excessively large volumes of embolic material or arterial spasm due to trauma from the guidewire or catheter Thus the potential complications are refer

Fig 3 Gelfoam sponges intact at top measuring 18 mm × 20 mm 3 mm Three strips from the sponge at bottom form emboli 1 mm 3 mm 18 mm The Gelfoam is cut with a scalpel blade

may fail to stop the bleeding because of undetected multiple bleeding sites or collateral blood supply In such cases angiography affords the opportunity to define more accurately the presence or absence of vascular injury and also lends confidence to the decision to defer immediate operation in favor of embolization

The catheterization technique as used in this case is worth further mention It is easier to catheterize the femoral artery and its branches selectively or superselectively when the catheter is introduced from the opposite femoral artery Difficulties may arise in negotiating the catheter over the aortic bifurcation This difficulty is overcome by using a guidewire with a removable core After the pre formed catheter curve has been reformed in the aorta the guidewire with the core partially removed is advanced peripherally into the opposite extremity The catheter can then be threaded over the guidewire to the desired level A short second steering b nd (Fig 1) on the catheter makes superselective catheterization easier

According to the time of persistence of embolic vascular occlusion embolic materials can be grouped as those of short and intermediate duration and those that give a permanent occlusion The most commonly used short acting material is autogenous blood clot (REUTER & CHUANG 1974) It has the advantage of being an endogenous material and fragments into many small emboli as it passes through the catheter This fragmentation of emboli is an important advantage because the many small embolic fragments shower the branches of the bleeding artery causing peripheral occlusion The more peripheral the occlusion the less the likelihood that collateral blood supply will develop around the occlusion The disadvantages with autogenous blood clot emboli are that almost complete lysis in injected clots usually occurs within 12 to 36 hours (GOLDSTEIN et coll 1975) In order to prolong the duration of the autogenous blood clots it has been mixed with epsilon aminocaproic

GOLD II E. and GRACE D M Gelfoam embolization of the left gastric artery for bleeding ulcer Radiology 116 (1975) 525
GOLDSTEIN H M MEDELLIN H BEN MENACHEM Y and WALLACE S Transcatheter arterial embolization in the management of bleeding in the cancer patient Radiology 115 (1975) 603
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ROSCH J DOTTER C T and BROWN M J Selective arterial embolization Radiology 102 (1972) 303

rable to inadequate angiographic technique Therefore embolization should only be performed by those who have had thorough experience in angiographic technique

Embolization is a practical simple and effective method to arrest arterial bleeding Despite considerable success with embolization in controlling arterial bleeding at different sites it is recommended that a clinical embolization be reserved for (1) poor risk patients not suitable for surgical therapy and in whom conservative hemostatic therapy has been unsuccessful and (2) patients with negative surgical exploration or in whom the predicted chances of finding the bleeding site by surgical exploration are minimal

SUMMARY

Superselective catheterization and Gelfoam embolization of a muscular branch of the deep femoral artery was successfully performed a profuse postsurgical bleeding requiring repeated transfusions of blood was stopped The time of persistence advantages and disadvantages of commonly used embolic materials are discussed It is concluded that embolization is an effective method to stop bleeding in selected patients

ZUSAMMENFASSUNG

Eine superselektive Katheterisierung und Gelfoam Embolisierung eines Muskelastes der Arteria profunda femoris wurden erfolgereich bei einer schweren postchirurgischen Blutung welche wiederholte Transfusionen verlangte ausgefuhrt Die Dauer der Embolisierung die Vorteile und die Nachteile der gewohnlich verwendeten embolischen Substanzen werden diskutiert Es wird festgestellt dass die Embolisierung eine effektive Methode ist bei ■ wissen Patienten eine Blutung zu stillen

RESUME

L auteur a realise avec succes un cathétérisme superselectif et une embolisation par le Gelfoam d une branche musculaire de l artère femorale profonde Un saignement post opératoire profus qui nécessitait des transfusions sanguines répétées a été ainsi arreté L auteur examine la duree de persistance les avantages et les inconvenients des matériaux utilises habituellement pour l embolisation Il conclut que l embolisation est une méthode efficace pour arreter les hémorragies chez des malades sélectionnes

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FROM THE DEPARTMENTS OF SURGERY (DIRECTOR PROF ■ BORGSTRÖM) AND DIAGNOSTIC RADIOLOGY (DIRECTOR PROF G F SALTZMAN) UNIVERSITY HOSPITAL, S 901 85 UMEÅ SWEDEN

EXTRAHEPATIC OBSTRUCTION OF THE PORTAL VEIN WITH BLEEDING FROM THE GALLBLADDER

Report of a case

D HOLMLUND and B LUNDSTRÖM

In extrahepatic obstruction of the portal vein a collateral system with hepatofugal blood flow generally develops just as in portal hypertension due to other causes Hepatopetal collaterals may also develop inter alia via veins in the wall of the gall bladder particularly in cases of obstruction to the portal flow in young patients Varicose veins in the gallbladder are indeed very rare (FELDMAN et coll 1942) and it seems as if bleeding from such veins has not previously been reported The present case is reported partly because of its rarity but mainly to illustrate the manner in which the collaterals around an extrahepatic obstruction may gradually change

Case report

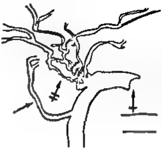
The patient was a girl who at 4 years of age fell ill with jaundice of the obstructive type which occasioned surgery This revealed a 5 cm × 5 cm fibrous tumour dorsal to the head of the pancreas causing virtually total obstruction of the common bile duct The tumour was considered inoperable and only a cholecystojejunostomy and an entero-anastomosis were

Submitted for publication 9 February 1977

Fig 1 Section from the gallbladder Varicose veins in the wall Van Gieson elastica ×25

performed Two years later the patient had a severe upper gastrointestinal haemorrhage Splenic portography revealed a marked concentric constriction of the extrahepatic part of the portal vein and hepatofugal circulation in the left gastric vein with large oesophageal varices Splenectomy was performed and a splenorenal anastomosis was established At this operation the tumour behind the head of the pancreas was found to be of the same size as 2 years before it was also evident that it caused a marked compression of the portal vein The tumour was still considered inoperable A biopsy provided the diagnosis of malignant neurolemmoma Following this operation the patient was irradiated with a tumour dose of 35 Gy (3 500 rad) One year later the patient again had a massive gastrointestinal haemorrhage but the source of the bleeding could not be located and it was assumed to be caused by the tumour Complementary treatment with telecobalt (tumour dose 15 Gy) was given Thereafter the condition of the patient was unremarkable for a period of 10 years but then she had a severe life threatening gastrointestinal haemorrhage No bleeding source in the stomach or duodenum was found at gastroscopy Laparotomy revealed blood in the jejunum and ileum The veins of the omentum stomach and bowels were not dilated but there were dilated tortuous varicose veins in the wall of the gallbladder and along the common bile duct The common duct was punctured and found to contain no blood No constriction of the bile ducts was found at cholangiography but the gallbladder was distended with blood The bleeding was considered to originate from varicose cystic veins The patency of the bile ducts now having been found to be normal a cholecystectomy was made and the cholecystojejunostomy performed 13 years previously was closed Microscopy of the gallbladder

a



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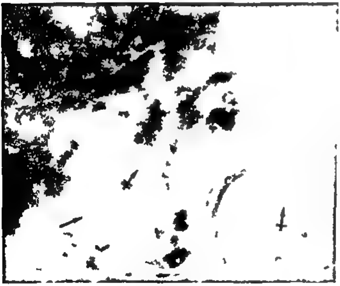

b

Fig [illegible] Angiography of (a) the coeliac artery (venous phase) (b) the superior mesenteric artery (venous phase) Subtraction films c) Schematic drawing Hepatopetal blood flow in the inferior pancreaticoduodenal vein (→) The splenorenal shunt occluded (↔) At the site of the previously compressed portal vein several small tortuous collateral veins leading to the intrahepatic branches of the portal vein (⇸)

demonstrated moderate fibrosis and varicose veins in the wall (Fig 1) The size of the tumour behind the head of the pancreas remained unchanged and it was left in situ A year later the condition of the patient was good according to both subjective and objective criteria Angiography of the coeliac and superior mesenteric arteries revealed no arterial abnormalities The splenoportal shunt could not be demonstrated which suggested thrombosis At the site of the previously demonstrated severe constriction of the portal vein numerous small tortuous collateral veins existed adjacent to the interhepatic branches of the portal system The left gastric vein and the inferior pancreaticoduodenal vein were filled and the flow of blood in these veins had now returned to normal into a hepatopetal direction (Fig 2)

Discussion

Portal hypertension secondary to obstruction of the main portal vein may lead to the development of collaterals both hepatofugal from and hepatopetal to the liver The clinically most important of the former type is the one with reversed blood flow into the left gastric vein with resultant oesophageal varices and the risk of haemorrhage In recent years however it has been demonstrated that other collateral pathways splenorenal and suprarenal collaterals are also common (SCHNEIDER & BLUMENSTEIN 1972 GÖTHLIN 1976)

The hepatopetal collaterals which normalize the portal blood flow consist of a complex network of veins adjoining the obstructed portal vein in the hepatoduodenal ligament hepatocolic ligament the peritoneal covering of the liver and not least veins in the wall of the gallbladder (RÖSCH & DOTTER 1971 MARKS 1974) These hepatopetal collaterals which empty into medium sized intrahepatic portal veins have sometimes been called cavernous transformations of the portal vein

In the present case the extrahepatic obstruction of the portal vein caused portal hypertension with oesophageal varices and bleeding in an initial phase Following a splenorenal shunt the portal hypertension was reduced and the oesophageal varices disappeared During the following years portoportal collaterals gradually developed and the blood flow through the splenorenal shunt decreased until the anastomosis finally became occluded by thrombosis It is primarily in children that portoportal anastomoses occur and their development appears to be a gradual process (JOHNS & BLACKWELL 1962) Concurrently with the development of the portoportal anastomoses which frequently takes months or years portal hypertension is reduced in patients with extrahepatic portal obstruction (NIELSEN et coll 1973) When the portoportal collaterals develop the process is accompanied by inter alia retrograde blood flow in the cystic vein (KREIDER 1933) which may give rise to varicose veins of the gallbladder The last episode of haemorrhage in the present patient was probably due to varicose veins of this type The fact that the haemorrhage was massive and life threatening may be explained in terms of the previously established cholecystojejunostomy which permitted free drainage for the venous blood

SUMMARY

A case of extrahepatic obstruction of the common bile duct and the portal vein by a retroperitoneal neurolemmoma is described In the initial stages portal hypertension with hepatofugal collaterals and bleeding from oesophageal varices existed Then gradually hepatopetal anastomoses developed partly via veins in the wall of the gallbladder Such venous collaterals tend to reduce the portal hypertension but may cause bleeding from the gallbladder

ZUSAMMENFASSUNG

Ein Fall mit einer extrahepatischen Obstruktion des Ductus choledochus und der Vena portae durch ein retroperitoneales Neurolemmom wird beschrieben Im initialen Stadium bestand eine portale Hypertension mit hepatofugalen Kollateralen und Blutungen von Ösophagusvarizen Dann entwickelten sich hepatopetale Anastomosen teilweise uber Venen in der Wand der Gallenblase Derartige venose Kollateralen mogen die portale Hypertension vermindern konnen jedoch eine Blutung in der Gallenblase hervorrufen

RESUME

Description d un cas d obstruction extra hépatique du canal cholédoque et de la veine porte par un neurolemmome retropéritoneal Aux stades initiaux il y avait une hypertension portale avec des collatérales hepatofuges et une hémorragie à partir de varices oesophagiennes Puis graduellement des anastomoses hépatopètes se sont développées en partie par des veines situées dans la paroi de la vésicule biliaire Les collatérales veineuses de ce type tendent à reduire l hypertension portale mais peuvent provoquer une hemorragie à partir de la vesicule biliaire

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THE SPHERICAL INDEX

A measure of the roundness of the femoral head

N FREDENSBORG

For the investigation of the results of treatment of congenital dislocation of the hip with the von Rosen splint (FREDENSBORG 1976) it was necessary to design a method for evaluation of the shape of the femoral head Several methods have been presented EYRE BROOK (1936) introduced the epiphyseal index to assess the results in Perthes s disease (coxa plana) Unfortunately the points of measurement are sometimes difficult to define and in older children and adults the remnants of the epiphyseal plate may be impossible to identify The comprehensive quotient introduced by HEYMAN & HERNDON (1950) includes measurement of the epiphyseal index and is therefore not applicable in older age groups A transparent template with concentric circles was used by MOSE (1964) as a method of assessing any deviation from the spherical shape of the femoral head This is a simple method but its use is restricted to patients with completed ossification of the femoral head as the capital epiphysis in children is flat MEYER (1966) added details to the method of MOSE but the measurements included require a number of geometrical drawings and calculations that are difficult to perform rather time consuming and unnecessary when assessing normal or only slightly deformed hips

The absence of an adequate method led to the design of a new index called the spherical index

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Fig 1 Adults The line (b) denotes the maximum width of the femoral head and (a) the maximum height measured from this line The line (b) passes the center of the femoral head and should be measured perpendicularly to the axis of the femoral neck and head a/b × 100 = spherical index

Fig 2 Children The line (b) denotes the maximum width of the capital epiphysis and (a) the maximum height measured from this line a/b 100 spherical index

Fig 1

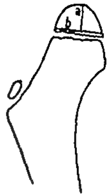

Fig 2

When this index was applied to cases with congenital dislocation of the hip it was found that the index rose gradually with age In the present report the spherical index in normal hips and in relation to age is described

Material and Methods

Standard pelvic films of normal hips in patients who had been examined because of trauma or transient hip pain were used Twenty hips—10 patients—of both sexes were recorded for ages 4 5 6 8 10 15 20 and 75 years Males and females were recorded separately No differences were found between right and left hips

The index is measured on a standard anteroposterior film taken in the supine position with the hips inwardly rotated The index is constructed as shown in Figs 1 and 2 and expresses in per cent the relationship of the maximum width of the femoral head or capital epiphysis and the maximum height measured perpendicularly to the line denoting the width A transparent ruler graduated in millimeters was used

Results

The spherical index was found to increase up to the age of 20 (Fig 3) After this age the spherical index was constant The curve was almost identical in both sexes The standard deviations indicate a considerable variation in the development of the ossified part of the capital epiphysis

Discussion

A suitable method for comparison between normal and slightly deformed hips should be simple and make use of standard films The acetabular part of the hip joint is most simply described by the CE angle (Wiberg 1939) or the acetabular angle

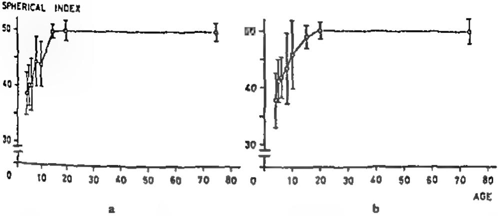

Fig 3 Spherical index in a) males and b) females Age ranging from 4 to 75 years Mean values and two standard deviations

(HILGENREINER 1935) The spherical index is a method of measuring the roundness of the femoral head or capital epiphysis However the anteroposterior view only discloses one aspect of a three dimensional head LAURITZEN (1975) applied the method of MEYER on both anteroposterior films and on films obtained in the Lauenstein position and found only small differences Nevertheless the spherical index should be measured only on films obtained in the standardized anteroposterior projection

SUMMARY

The spherical index is introduced as a new simple method of measuring the roundness of the femoral head and capital epiphysis The index may be applied both in children and adults Means and standard deviations are presented for both sexes in different age groups The index increases with age until maturation In adults the index is constant

ZUSAMMENFASSUNG

Der spharische Index wurde als eine neue einfache Methode zur Messung der Rundung des Femur Kopfes und der oberen Epiphyse eingefuhrt Dieser Index kann bei Kindern wie Erwachsenen verwendet werden Mittelwerte und Standard Abweichungen werden fur beide Geschlechter in verschiedenen Altersgruppen gegeben Der Index steigt mit dem Alter bis zur Reife Bei Erwachsenen ist der Index konstant

RESUME

L auteur presente l index sphérique comme une methode nouvelle et simple pour mesurer la rotondité de la tete fémorale et de l épiphyse de la tete femorale Cet index peut être appliqué chez les enfants et chez les adultes L auteur indique les moyennes et les deviations standards pour les deux sexes dans différents groupes d ages Cet index augmente avec l âge jusqu à la maturation chez les adultes cet index est constant

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY THE MEDICAL SCHOOL LINKOPING UNIVERSITY S 581 ■ LINKÖPING SWEDEN

DETERMINATION OF SAGITTAL INSTABILITY OF THE KNEE JOINT

HANS LEVEN

Sagittal instability of the knee joint has long been linked with injury to the cruciate ligaments The presence of significant sagittal instability implies injury also to the medial collateral ligament and to the joint capsule as demonstrated by PALMER (1957) among others In rupture of the capsule and the deeper part of the medial collateral ligament there ensues a rotatory as well as a sagittal laxity this has been pointed out by BRANTIGAN & VOSHELL (1941) SLOCUM & LARSSON (1968) and KENNEDY & FOWLER (1971) It is thus necessary to discriminate between these two components of instability

The sagittal mobility in the flexed knee joint is normally about 5 mm (PALMER) while values exceeding 10 mm are definitely abnormal This observation is consistent with those reported by among others KENNEDY & FOWLER and VOLKOV (1971) On the other hand BRANTIGAN & VOSHELL considered that the normal knee joint has no demonstrable sagittal mobility

Clinically sagittal instability of the knee joint is usually recognized by what is known as the drawer sign in which the laxity is felt by the examiner with his hands on drawing the tibia sagittally on the femur However it is for several reasons desirable to have a reproducible method for measurement of sagittal instability—for example in order to assess the value of reconstructive or reparative surgery on the knee joint Moreover in case of possible ligamentous insufficiency of one side comparison with the other knee joint is of great value As demonstrated by SYLVIN (1975)

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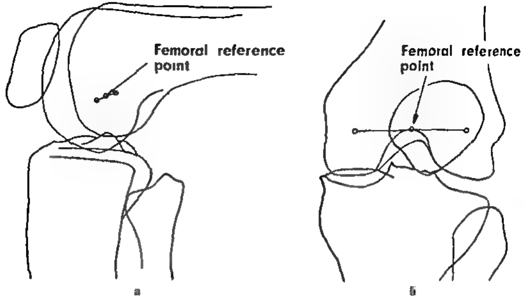

Fig 1 Femoral reference point a) Lateral projection b) A p projection

the difference in sagittal mobility for the two normal knee joints in the individual subject is extremely small

Previous measuring methods In the method devised by VOLKOV the lower leg and the femur are immobilized and forward traction is then applied to the lower leg with a force that is measured with a dynamometer VOLKOV considered a displacement of the lower leg exceeding 10 mm in relation to the femur to be abnormal The displacement of the lower leg is measured on films exposed in a lateral projection No further details of this technique were given however KENNEDY & FOWLER designed an apparatus called a clinical stress machine in which the immobilized lower leg is displaced in the sagittal direction and rotated by means of a hydraulic system The mobility is measured on lateral films No reference points for measuring were defined and the reproducibility of the method is therefore doubtful

SYLVIN has described a measuring which is applied directly to the leg and which shows the forward displacement obtained when the anterior drawer sign is tested manually However if a rotatory instability is also present there is a risk that with this technique it will be confused with sagittal instability and thus give a misleading impression as to which ligament is torn

At this hospital a modification of the technique for knee arthrography described by LINDBLOM (1948) has been applied since 1971 The modification consists in the use of TV fluoroscopy examination of the joint in extreme varus and valgus positions and the use of primary dodging An arrangement for generating constant static forces employed for varus and valgus rocking was also used to produce traction on

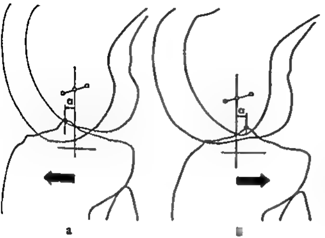

Fig 2. The displacement of the tibial reference point from (a) to (b) represents the sagittal instability

the lower leg in the forward and backward directions in relation to the femur (LEVEN 1974)

The diagnosis of cruciate ligament injury with this method is based on two observations namely an identification of the ligament on lateral films with and without provocation of sagittal instability and an estimate of the magnitude of the sagittal laxity However an apparently normal ligament at arthrography is in fact often present even in extensive lesions of the ligament owing to synovial structures that are not disrupted Moreover the cruciate ligaments might be functionally incompetent without total disruption A mere estimation of sagittal instability in the joint is of course less satisfactory as it does not provide the objective evaluation that is essential in radiologic diagnosis

With the object of improving the diagnosis of injury of ligaments a method has been developed to measure the instability

Present method

The method is based on measurement of the positional relationship between one reference point in the femur and another in the tibia The patient is placed on an examination table in the lateral position with the knee flexed so that the tibia and femur make an angle of about 130 In this position the line on the film corresponding to the roof of the femoral intercondyloid fossa is parallel to the plane of the articular surface of the tibia By means of two slings placed around the lower leg a static traction force is applied in a forward direction in relation to the femur A lateral film of the knee joint is exposed The slings are then adjusted so that the lower leg is pushed in the backward direction in relation to the femur and another lateral film is exposed The magnitude of the applied force is about 150 N (15 kp) At the end of the tension the sling is secured to the edge of the table with a clam cleat (LEVEN 1974 Fig 1 c)

The femoral reference point in the two films is constructed by means of a trans

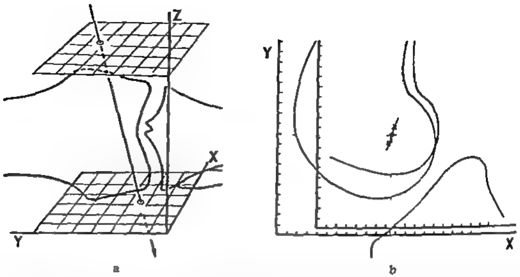

Fig 3 a) System for determining the position of the reference point in the femur with different oblique projections b) Diagrammatic representation of lateral film taken with this system The femoral reference point is the midpoint between the two centres of curvature for the femoral condyles This point represents a ray passing through the two coordinate systems By means of the two lines the coordinates for the path of the ray through the two coordinate systems can be determined and thus the space coordinates for the ray

parent disc bearing arcs of circles with radii ranging from 20 to 28 mm For both the tibial and the fibular femoral condyles a centre of curvature is defined by aligning a suitable arc to the posterior parts of the condylar bone surface The centres of curvature for the two condyles are generally projected some distance apart A line is drawn between the points and its midpoint is taken as the femoral reference point (Fig 1)

The tibial reference point should be a readily identifiable point centrally located in the upper tibia such as the most superior pointed part of the tibial eminence It is almost always the medial part of the eminence and is located close to the axis of rotation thus not being significantly displaced on rotation of the lower leg This is important as on application of traction force to the lower leg a rotatory component often occurs This particular tibial reference point can usually be identified if a somewhat oblique projection is used with the central ray directed slightly from below If not it is necessary to use as the tibial reference point a less centrally located point of the upper tibia—for example the posterior or anterior borders of the articular surface this is acceptable if no rotation of the lower leg has occurred

On the two films a reference line is drawn parallel to the upper articular surface of the tibia From the femoral reference point a perpendicular is drawn to this reference line The sagittal distance between this normal line and the tibial reference point is measured on the two films and the difference constitutes the sagittal displacement of the tibia (Fig 2) This technique in common with all measurement methods has a number of sources of error The effect of some of these has been analysed

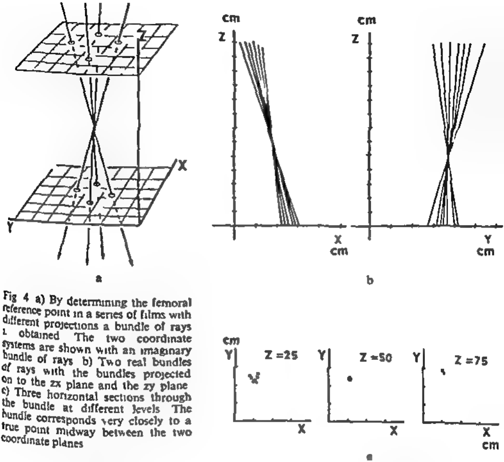

Fig 4 a) By determining the femoral reference point in a series of films with different projections a bundle of rays is obtained The two coordinate systems are shown with an imaginary bundle of rays b) Two real bundles of rays with the bundles projected on to the zx plane and the zy plane c) Three horizontal sections through the bundle at different levels The bundle corresponds very closely to a true point midway between the two coordinate planes

Effect of oblique projection on the position of the femoral reference point The method for defining a femoral reference point consists in reconstructing the position of an actual anatomic point within the femur and marking it on the films However the location of this point is based on determination of the centres of curvature of the projected femoral condyles and it is conceivable that for different directions of projection there is a difference in the curvature of the condyle surfaces and hence in the centres of curvature and in the position of the reference point In order to assess the magnitude of these errors experiments were performed on 4 knee joints

With the patient in the lateral position on the examination table of a polytome with a free choice of beam direction the central ray was adjusted to give an exact lateral projection Two straight edges with graduations were placed in the horizontal plane one on the table beneath the knee joint and the other above the knee perpendicular to the first one The tube was then adjusted with the central ray at an angle of 5 from the vertical perpendicle A number of films were exposed from different directions The tube was then set at the angles 10 15 and 20 to the vertical

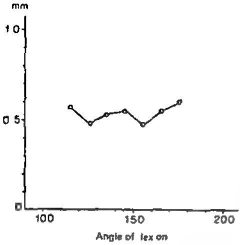

Fig 5

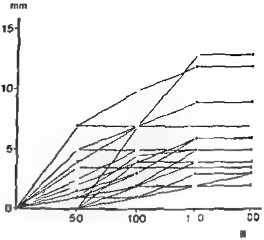

Fig 6

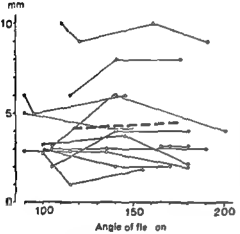

Fig 7

Fig 5 Measurement error incurred on changing the angle of flexion when determining the position of the femoral reference point

Fig 6 Sagittal displacement in mm between tibia and femur with different degrees of traction force

Fig 7 Sagittal instability in mm in the knee joint in different degrees of flexion

and for each angle several exposures were taken from different directions of the knee joint A series of films of the same knee joint with different projections was thus obtained On each film the femoral reference point was determined The two straight edges one on each side of the knee joint determined a plane horizontal coordinate system (Fig 3 a) For each projection the ray corresponding to the reference point intersected the two coordinate planes and its coordinates for each plane were read off directly from the films The rays through the reference point for the different projections were thus reconstructed (Fig 3 b) By means of a desk computer (Hewlett Packard 9830) these rays were plotted in two projections and their intersection with different horizontal planes were determined (Fig 4)

It was found that even with a very oblique projection (20) the femoral reference point corresponded closely to a definite anatomic point in the femur and that this point was located half way between the two femoral condyles The sagittal standard

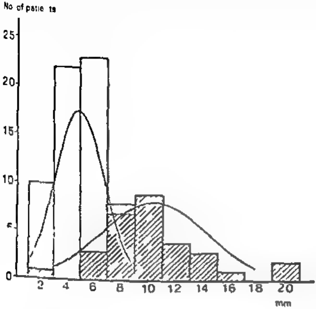

Fig 8 Magnitude of sagittal displacement in normal subjects [hatched] and in patients with torn cruciate ligaments [open]

deviation of the position of the point in a horizontal plane midway between the two femoral condyles for 22 measurements with a 10° oblique projection was 0 35 mm and for a 15° oblique projection 0 55 mm

Position of the femoral reference point for different flexion angles Ideally the femoral reference point should be located on the axis of flexion of the knee joint as its position in relation to the tibia would then not change on flexion However no constant axis of flexion exists and when the angle of flexion is altered a change in the sagittal position of the reference point in relation to the tibia occurs This was examined in detail in a separate experiment

In 12 patients the sagittal position of the femoral reference point in relation to the tibia was determined for different angles of flexion of the knee joint while traction was applied to the tibia It was found that when the angle of flexion was altered the reference point was displaced a short distance in relation to the tibia in a manner suggesting that it was located slightly above the axis of flexion Thus when the two films were exposed with a different angle of flexion an error will have been incurred in the measurement of the sagittal displacement With a difference of 10° in the angle this error was on an average 0 56 mm (Fig 5)

Variation of the sagittal displacement with the traction force In 20 patients with possible injury to the ligaments or menisci sagittal instability was measured by the present method and with traction forces of approximately 50 100 150 and 200 N in the forward direction The force was generated by means of weights attached to a string running over a pulley fixed to the edge of the examination table The sagittal

displacement was observed to increase with the force at a diminishing rate Above the level of 141 N practically no further increase of displacement occurred (Fig 6)

Variation in sagittal instability with flexion angle In 12 patients the sagittal in stability of the knee joint was measured for different angles of flexion (Fig 7) No systematic variation in the sagittal displacement with the angle of flexion was found

Reproducibility of the method Assessment of the sagittal instability was repeated in 10 patients After one set of films (Series 1) had been exposed the patient was asked to walk around a new series of films (Series 2) was then taken The measurements were performed by two radiologists working independently In none of the patients did the values for sagittal displacement differ by more than 2 mm The values ob tained in the 2 series were

Series 1 8 3 5 4 7 5 6 8 14 4 mm
Series 2 9 4 5 6 8 7 7 9 12 6 mm

Clinical test of the method Measurements can be made directly on arthrographic lateral films if the contrast medium in the joint does not obscure the tibial reference point

In an arthrographic series consisting of 132 patients the measuring technique could be used in 93 in the remaining 39 the tibial reference point was concealed by the contrast medium At operation 63 of the patients were found to have normal cruciate ligaments and 30 had a torn anterior cruciate ligament On traction the mean sagittal displacement was 4 92 mm with a standard deviation of 1 82 mm in the normal group in the group with a torn anterior cruciate ligament the mean displace ment was 10 4 mm with a standard deviation of 3 87 mm (Fig 8)

SUMMARY

For measuring sagittal instability in the knee joint a radiologic method has been developed which requires no complicated equipment is easy to apply and is relatively insensitive to the sources of error commonly associated with determination of sagittal instability such as difference of flexion angle and changes in the projection Measurements are made between reference points located in the femur and the tibia The reproducibility of the method is high enough to make it suitable for testing instability before and after reconstructive surgery By the use of constructed reference points sagittal instability can be distinguished from rotational instability

ZUSAMMENFASSUNG

Zur Messung der sagittalen Instabilitat des Kniesgelenks wurde eine rontgenologische Methode entwickelt welche keine komplizierte Ausrustung verlangt leicht anzuwenden ist und relativ unempfindlich gegenuber den Fehlerquellen ist, die gewohnlich mit der Be stimmung der sagittalen Instabilität verbunden ist wie die Differenzen des Beugungswinkels

und Änderungen in der Projektion Messungen zwischen Referenzpunkten die im Femur und der Tibia lokalisiert waren wurden durchgefuhrt Die Reproduzierbarkeit der Methode ist gut genug um diese geeignet zu machen um die Instabilitat vor und nach rekonstruktiver Chirurgie festzustellen Durch Verwendung der konstruierten Referenzpunkte ist die sagittale Instabilitat von der Rotationsinstabilität zu unterscheiden

RESUME

Pour mesurer l instabilite sagittale dans l articulation du genou l auteur a mis au point une methode radiologique qui ne nécessite pas d équipement compliqué qui est facile à appliquer et qui est relativement insensible aux sources d erreurs qui affectent habituellement la détermination de l instabilité sagittale telle que la différence d angle de flexion et les changements de l incidence Les mesures sont faites entre des points de référence situés sur le fémur et le tibia La reproductibilité de cette méthode est assez élevée pour la rendre applicable à la determination de l instabilité avant et après chirurgie reconstructrice L utilisation de points de référence construits permet de distinguer l instabilité sagittale de l instabilite rotatoire

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GASTROCNEMIO-SEMIMEMBRANOSUS BURSA AND ITS RELATION TO THE KNEE JOINT

II Post mortem radiography

PER GUNNAR LINDGREN

The gastrocnemio semimembranosus bursa is located in the medial part of the popliteal region posterior to the knee joint capsule (Fig 1) The bursa often communicates with the knee joint through a slit shaped opening in the joint capsule posterior to the medial femoral condyle (Fig 2) Such a communication is found more frequently in older people Thus in a large series of autopsy cases no communication between the joint and bursa was found in children up to 10 years old while in adults over 50 years of age this was observed in more than 50 per cent (LINDGREN 1977c)

When the bursa is expanded it is often called a Baker s cyst after BAKER (1877 1885) who described a cystic swelling at the back of the knee ADAMS (1840) had reported a similar swelling and considered it to be due to an enlarged gastrocnemio-semimembranosus bursa communicating with the knee joint The bursa may be demonstrated in different ways at radiography BEATTY (1959) BURLESON et coll (1956) and GRISTINA & WILSON (1964) used the technique of soft tissue radiography Arthrography with air as contrast medium was employed by CRAVENER (1932) QUAINTANCE (1938) KUHN & HEMPHILL (1944) and LINDBLOM (1948) used a water soluble contrast medium

Several other authors have proved the value of arthrography with positive contrast medium for demonstrating the gastrocnemio-semimembranosus bursa e g DOPPMAN (1965) FISCHEDICK (1969) and REINHARDT (1972) WILSON et coll (1938) made a

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Fig 1 In the medial part of the popliteal region the gastrocnemio-semimembranosus bursa is filled with Urografin 45 injected into the knee joint

Fig 2 The medio-posterior part of the joint capsule viewed from the knee joint A slit in the capsule towards the gastrocnemio-semimembranosus bursa T = tendon of the medial head of the gastrocnemius muscle

thorough anatomic investigation of the bursae in the popliteal region on an autopsy material

The aim of the present report is to describe the radiographic appearance of the gastrocnemio semimembranosus bursa and the adjacent posterior part of the joint

Material and Methods

Radiography was performed in 15 autopsy cases including both cases with and without communication between the knee joint and the gastrocnemio semimembranosus bursa In no case was the bursa distended or palpable at the time of examination and neither was there any known joint disease

Arthrography of the knee joint was performed using a contrast medium consisting of plaster of Paris mixed with 3 parts water and 1 part water soluble contrast medium (Angiografin 65) giving a solution of low viscosity

Usually 20 ml of this plaster solution were in cted into the knee joint in the same

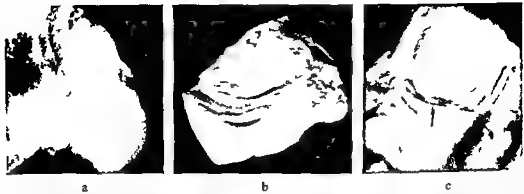


Fig 3 a) Plaster solution in the medio posterior part of the knee joint An impression dorsally is due to a fold in the capsule immediately distal to the site at which the gastrocnemius muscle leaves the joint capsule b) The cast after setting of the plaster solution Folding of the joint capsule has caused a transverse impression on the cast Viewed from behind c) The joint capsule specimen with the folding (→) causing the impression observed in (a) The specimen is viewed from the knee joint

way as in clinical knee arthrography The knee was then flexed allowing the bursa to be filled with plaster solution in cases where the joint and bursa communicated In 2 cases plaster solution was injected directly into the bursa after this had been exposed by dissection Each knee was then fixed at a given degree of flexion or maximum extension and radiography was performed

The plaster solution set in less than 4 hours Thereafter the casts of the bursa and of the medio posterior capsular recess were removed by dissection together with adjacent tissues During the dissection the different impressions in the casts were noted

Results

In cases where no communication existed between the knee joint and the bursa a localized impression with a specific appearance in the medio posterior part of the joint capsule was observed (Fig 3 a) During the removal of the plaster cast this was seen to consist of a fold in the joint capsule immediately distal to the site at which the tendon of the medial head of the gastrocnemius muscle left the capsule (Fig 3 b c) This fold only occurred on flexion of the knee joint

In one case the impression was more marked and located somewhat further distally than in the other cases In this case there was no folding of the capsule but a slit shaped opening oriented towards the gastrocnemio semimembranosus bursa filled with contrast medium (Fig 4 a) A membrane in the bottom of the slit prevented passage between the joint and bursa (Fig 4 b) Such membranes have been demonstrated previously in autopsy cases (Lindgren & Willén 1977)

With the knee in the flexed position different impressions were evident in the bursa on the films A well defined impression ran parallel with the femur and another with the tibia (Fig 5 a) An irregular thin linear impression is also present in the

a b

Fig 4 a) Plaster solution in the joint filling the postero-medial capsular recess and a slit in the capsule b) Cross section of the preparation The arrow points at a membrane bridging the lower part of the slit J = knee joint S = slit B = bursa

upper and middle parts of the bursa and small rather irregular pouches in its upper and lower parts (Fig 5) During the removal of the plaster cast it was established that the impression running parallel with the femur was caused by the semimembranosus muscle (Fig 5 b) and that running parallel with the tibia by the medial head of the gastrocnemius (Fig 5 c) The linear impression in the upper and middle parts of the bursa (Fig 5 a) was caused by a thin fibrous septum which partially divided the bursa and the pouches were due to diverticular formations (Fig 5 b c)

On maximum extension of the knee no contrast medium filled the middle and anterior parts of the bursa (Fig 6 a) During the removal of the plaster cast it was found that the bursa was completely compressed by the gastrocnemius (medial head) semimembranosus and to a small extent the semitendinosus muscle (Fig 6 b c) The slit between the joint and bursa did not fill with contrast medium on maximum extension of the knee

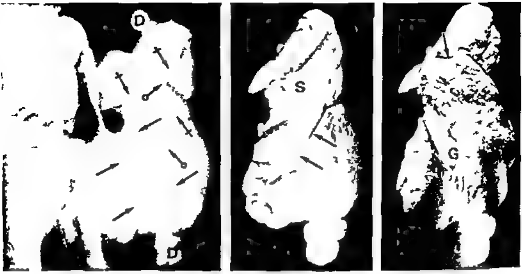
Following direct injection of plaster solution into the bursa the resultant plaster casts had the same appearance as those obtained after injection into the knee joint in cases where the joint and bursa communicated

Discussion

The plaster solution used as contrast medium had an attenuation similar to water soluble contrast media generally used in arthrography e g Urografin 45% (cf Figs 1 5 a)

Despite the fact that the plaster of Paris was mixed with a relatively large quantity of fluid the plaster solution set to a firm cast in less than 4 hours This could then be removed during the dissection of the popliteal region

Several attempts were made to use various plastic materials as the cast agent but the low temperature of the autopsy material prevented setting of the cast Only



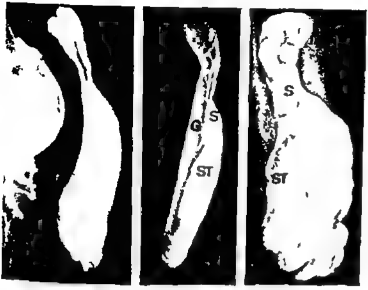
a b c

Fig 5 a) Plaster solution injected into the knee joint has filled the posterior part of the joint capsule and the gastrocnemio-semimembranosus bursa Impression caused by the gastrocnemius muscle (→) the semimembranosus muscle (↔) and a thin fibrous septum (o→) D – diverticula of the bursa b) The plaster cast after setting of the plaster solution seen from the medial side S – impression caused by the semimembranosus muscle The arrows indicate impressions due to a thin fibrous septum c) Same plaster cast seen from the lateral side The photograph has been reversed to correspond to (a) G – impression caused by the medial head of the gastrocnemius muscle The arrows indicate impressions due to a thin fibrous septum

lateral views of the plaster casts are given in the figures as no further information was obtained from a p films

At clinical arthrography an impression may be observed in the medio posterior part of the knee joint capsule when the knee is flexed Films exposed after injection of plaster solution into the knee joint in the present autopsy material had a similar appearance (Figs 3 a 4 a) On removal of the plaster cast it was established that this impression was located at the usual site of the slit in the joint capsule i e where the tendon of the medial head of the gastrocnemius leaves the joint capsule The impression was due either to a fold or a slit in the joint capsule With the knee flexed and with an ideal projection an impression caused by a fold in the joint capsule may be seen in the majority of cases at clinical arthrography On the other hand contrast filling of a slit without there being a communication between the joint and bursa is rare Such a slit is located somewhat further distally than the fold and the impression is also usually more marked in these cases It is sometimes difficult to differentiate between a fold and a slit in the joint capsule at radiography

During removal of the plaster casts it was established that the different impressions in the bursa were caused by the gastrocnemius muscle (medial head) the semimembranosus muscle and in certain cases by thin fibrous septa The semitendinosus muscle lies medio-dorsal to the semimembranosus muscle and may contribute to the



a b c

Fig 6

Fig 7

Fig 6 Maximum extension of the knee a) Plaster solution injected into the knee joint is filling the posterior part of the gastrocnemio-semimembranosus bursa The anterior part of the bursa is compressed between the semimembranosus and semitendinosus muscles and the medial head of the gastrocnemius b) The cast after setting of the plaster solution viewed from the side c) Same cast, seen from the posterior aspect The impressions indicate where the bursa is partially compressed G = gastrocnemius (medial head) S = semimembranosus ST = semitendinosus

Fig. 7 Plaster solution filling the anterior (V) and posterior (D) parts of the gastrocnemio-semimembranosus bursa The middle part is firmly compressed between the gastrocnemius and semimembranosus muscles Maximum extension of the knee

impression caused by the latter The popliteal artery popliteal vein and popliteal nerve are located lateral to the semimembranosus muscle and the medial head of the gastrocnemius muscle and caused no impression in the bursa in any of the cases

On maximum extension of the knee the gastrocnemius and semimembranosus muscles were so strongly compressed against each other that the middle part of the bursa did not fill with the plaster (Fig 6 a) In this case because of the forcible muscular compression the anterior part of the bursa was not filled either The anterior part of the bursa may however be partially filled on maximum extension of the knee (Fig 7) Neither could any plaster solution be forced from the posterior to the anterior part of the bursa in this position of the knee

Further on maximum extension of the knee no filling of the slit shaped opening between the joint and bursa was obtained as this slit was firmly compressed between the medial femoral condyle and the medial head of the gastrocnemius

The impressions in the bursa due to muscles and fibrous septa as well as the diverticular formations are also visible at clinical arthrography when the bursa is filled with contrast medium The outline of the bursa is generally even and impres

sions are usually only caused by the gastrocnemius and semimembranosus muscles (Fig 1) The size of the bursa varied as described elsewhere (LINDGREN 1977) Regardless of their size the bursae in this material exhibited the same relations to surrounding structures and the muscle impressions were present in all cases

Conclusions An impression with a specific appearance in the medio posterior part of the knee joint was found to be due to folding of the joint capsule immediately distal to the site at which the medial head of the gastrocnemius muscle left the capsule A more evident impression was caused by a slit shaped opening oriented towards the bursa

Impressions observed in the bursa on flexion of the knee were due to the semimem branosus muscle and the medial head of the gastrocnemius Fibrous septa in the bursa also caused minor impressions in some cases and diverticular formations were also observed On maximum extension of the knee joint the middle and also the anterior parts of the gastrocnemius were firmly compressed by the gastrocnemius and semimembranosus muscles and to some extent by the semitendinosus muscle The popliteal nerve artery and vein caused no impressions in the bursa

SUMMARY

The radiographic appearance of the gastrocnemio-semimembranosus bursa and the adjacent posterior part of the knee joint are described

ZUSAMMENFASSUNG

Das rontgenologische Bild der Bursa musculi gastrocnemii et semimembranosi und des anschliessenden oberen Teils des Kniegelenks wird beschrieben

RESUME

L auteur decrit l aspect radiologique de la bourse commune au jumeau interne et au demi *membraneux et la partie adjacente posterieure de l articulation du genou*

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(For further references see part I)

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BLURRING AND LAYER THICKNESS IN NARROW BEAM ROTATION RADIOGRAPHY

U WELANDER and G WICKMAN

When an object is reproduced on a roentgen film a certain blurring is always incorporated in the image This is partly due to geometric errors and partly to the properties of the recording medium Magnification of the exposed image does not affect the relation between the size of the object details and the blurring both the object and the inherent blurring of the image are uniformly magnified (Fig 1) Thus a relative value of the blurring taking into account the degree of magnification gives a more reliable and true measure of the blurring than does the total or absolute value

In previous publications where the blurring and the layer thickness in narrow beam rotation radiography have been calculated mathematically the total value of the blurring has been used (HUDSON et coll 1957 TAMMISALO & NIEMINEN 1964 WELANDER 1974 1975) However in an analysis of the layer formation in narrow beam rotation methods WELANDER (1975) points out that the characteristic blurring of these methods is highly dependent on the geometric properties of the image In fact the total blurring is directly proportional to the magnification factor in the rotation plane The magnification factor varies significantly with the position of the object in relation to the sharply depicted object plane Therefore it should be correct to define not only a total value of the blurring in rotation narrow beam radiography but also a relative value considering the magnification of the image

Submitted for publication 27 December 1976

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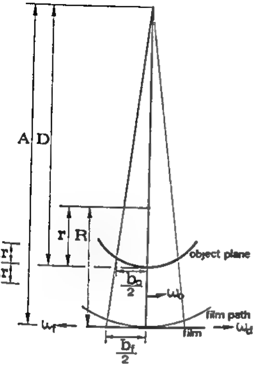

Fig 2 Essential parameters in narrow beam rotation radiography

where $b_0 = b_f(D+\Delta r)/A$ because the width of the divergent beam varies within the object It may be said that eq (1) expresses the total length of a theoretically ideal ine spread function it is additionally assumed that the tube target is a point source

The magnification factor M in the rotation plane is found from

$$M = \frac{R(\omega_0 - \omega_d)}{(r+\Delta r)\,\omega_0} = \frac{rA}{D(r+\Delta r)} \tag{2}$$

The relative length of the spread function is found when its total length is divided y the magnification factor $U_{wr} = U_w/M$

$$U_{wr} = \left| b_0 - \frac{b_f}{M} \right| \tag{3}$$

After substitution eq (3) may be written

$$U_{wr} = \frac{b_f\,\Delta r}{rA}\,|r-D| \tag{4}$$

Eqs (3) and (4) may be used to calculate the relative blurring of narrow beam tation radiography defined as the relative length of a theoretically ideal line spread nction The relation between the total and the relative length of this line spread

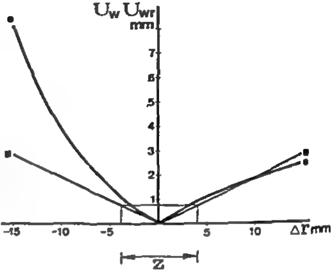

Fig 3 Relation between total and relative blurring in narrow beam rotation radiography It is evident that a calculated value of the layer thickness z, will be smaller when the calculation is based on the total blurring than when based on the relative blurring, the latter being more reliable than the former ■ relative blurring, U_{wr}, ● total blurring, U_w

function is illustrated in Fig 3 The functions are calculated from eqs (1) and (3) respectively It is seen that the relative length of the line spread function i e the relative blurring, is a linear function of Δr which expresses the distance by which the object is separated from the centre of the sharply depicted object plane

In the following experiments the full width at half maximum of the measured line spread function FWHM was selected as the definition of the blurring The length of the ideal line spread function and the FWHM are not identical It seems plausibe to assume that their correlation is linear In this case the FWHM should be found from the expression

$$U_{wr} = k_1 U_{wr} + k = \frac{k_1 b_f \Delta r}{rA} |r - D| + k \tag{5}$$

where k_1 and k are the regression constants

Experiments In the Orthopantomograph 3 a film series was exposed using a specially designed test object (Fig. 4) The object consisted of two parallel gold threads diameter 60 μm placed vertically at a distance of 2 0 mm The test object was attached to a slide that could be moved backwards and forwards with the aid of a graded micrometer screw With the test object positioned straight forwards in the midline of the Orthopantomograph exposures were made utilizing the rotation centre for exposure of the anterior part of the object When the films were exposed the test object was initially positioned well behind the sharply depicted object plane Then exposures were performed at each mm forwards Two extra films were exposed with the object positioned in the centre of the object plane the position of which was estimated when the films had been developed and analysed one of these films was exposed without rotation Non screen film was used and 60 kV and 15 mA

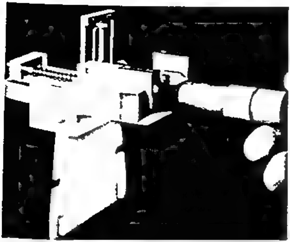

Fig. 4 Test object Two gold threads diameter 60 μm are placed in the open slit of the vertical support

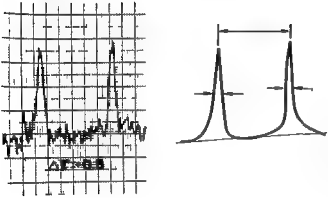

Fig 5 Microdensitometric scanning across one image of the two gold threads Distance between the two line spread functions and the full width at half maximum (FWHM) measurements indicated in the diagram.

The test films exposed with the test object positioned within $\pm 5\ 5$ mm from the centre of the object plane were evaluated with the aid of a microdensitometer Diagrams were drawn of the density variations across the images of the gold threads (Fig 5) In the diagrams the line spread functions are represented The widths of these line spread functions at half maximum were measured The distances between the centres of the line spread functions were also measured in all the diagrams (Fig 6) in order to obtain the magnification factors M Then the FWHM values were found by dividing the measured widths of the line spread functions by the corresponding magnification factor

Results The experimentally found values of the magnification factor agreed closely to expected data calculated from eq (2) (Fig 7) The regression constants were found to be 1 01 and 0 03 respectively the determination coefficient was 0 98

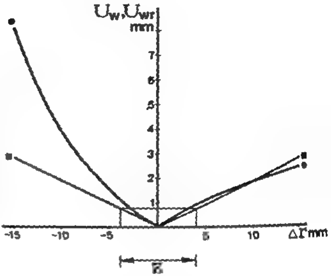

Fig 3 Relation between total and relative blurring in narrow beam rotation radiography It is evident that a calculated value of the layer thickness z_i will be smaller when the calculation is based on the total blurring than when based on the relative blurring, the latter being more reliable than the former ■ relative blurring, U_{wr}, ● total blurring U_w.

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$$U_{wr} = k_1 U_{wr} + k_2 = \frac{k_1 b_r \Delta r}{rA} |r - D| + k_2 \quad (5)$$

where k_1 and k are the regression constants

Experiments In the Orthopantomograph 3 a film series was exposed using a specially designed test object (Fig 4) The object consisted of two parallel gold threads diameter 60 μm placed vertically at a distance of 2 0 mm The test object was attached to a slide that could be moved backwards and forwards with the aid of a graded micrometer screw With the test object positioned straight forwards in the midline of the Orthopantomograph exposures were made utilizing the rotation centre for exposure of the anterior part of the object When the films were exposed the test object was initially positioned well behind the sharply depicted object plane Then exposures were performed at each mm forwards Two extra films were exposed with the object positioned in the centre of the object plane the position of which was estimated when the films had been developed and analysed one of these films was exposed without rotation Non screen film was used and 60 kV and 15 mA

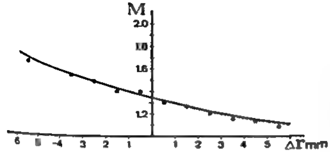

Fig 7 The magnification factor as a function of Δr Dots experimentally measured values line theoretically calculated function

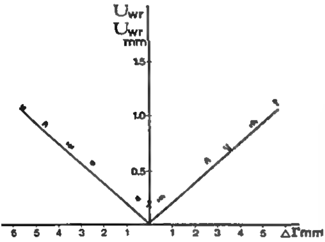

Fig 8 The relative blurring as a function of Δr Dots experimentally measured values Broken line measured function (U_{wr}) by linear regression Full drawn line theoretical ideal function (U_{wr}) is given for comparison

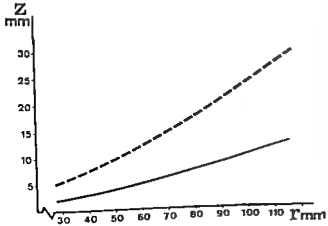

Fig 9 The layer thickness z, as a function of the object projection radius r when the tolerable relative blurring expressed as the FWHM is set to 0 3 and 0 5 mm respectively The functions are valid for the Orthopantomograph 3 used in the experiments In practice the layer thickness will be narrower due to the loss of resolution in the recording medium, varying with the screen film combination used

where a certain FWHM occurs It has been shown that the FWHM is a linear function and symmetrical around the object plane Thus the complete expression of the layer thickness may be written

$$z = 2|\Delta r| = 2\left|\frac{rA(U_{w} - k)}{k_1 b_f (r - D)}\right| \tag{7}$$

The layer thickness plotted as a function of the object projection radius $z = f(r)$ is illustrated in Fig 9 the function is valid provided that the regression constants are the same in the lateral parts of the image as in the anterior part

Discussion

Since PAATERO (1949 1954) presented the basic reports that started the development of rotation narrow beam radiography the method has been described as a modified form of tomography In a series of works WELANDER et coll have emphasized that narrow beam rotation radiography is primarily based on a projection technique and that the layer formation should be regarded as being a secondary effect at the exposure This view is based on mathematical calculations on different aspects of the image formation However the fundamentals of this view were empirically put forward already by HECKMANN (1939)

A close analysis of narrow beam rotation radiography reveals that the geometric properties of the image i e the degree of magnification significantly affect the total blurring of the image It should be most proper therefore to use the relative value of the blurring in calculations concerning the layer thickness When the total value is used in such a calculation a false result is obtained which gives a value of the layer thickness smaller than the real value (Fig 3) The expression of the layer thickness presented here is only applicable when the regression constants are known and these constants will vary between different equipments different tube target sizes and different screen film combinations It should be observed that the regression constants also will vary with the definition of the blurring the constants here presented are only valid when the FWHM is used to define the blurring When the regression constants are excluded from the expression of the layer thickness the remaining equation provides however important information Then it gives the layer thickness when the length of a theoretically ideal line spread function defines the blurring and no consideration is taken to the size of the tube target This simplified form of the expression may be used as a tool in calculating the theoretical limits of the layer thickness given by the movement pattern of a certain equipment

In the present investigation an extremely good correlation was found between theoretically calculated and experimentally found data This statement is valid with regard to the blurring of the image as well as the geometric properties expressed by the magnification factor The correlations found convincingly prove the validity of

the theoretical calculations These calculations are based on the mathematical model of narrow beam rotation radiography deduced by WELANDER (1974) Therefore the correlations now demonstrated retrospectively prove the validity of the mathematical model

SUMMARY

The definition of the blurring of narrow beam rotation radiography is revived The relative value of the blurring is considered to be the most reliable measurement Calculations of the layer thickness should be based on the definition of the relative blurring Experimental tests were performed which confirm the mathematically presented hypothesis and also confirm the validity of the mathematical model of narrow beam rotation radiography presented by WELANDER (1974)

ZUSAMMENFASSUNG

Die Definition der Verzerrung der Feinstrahl Rotations Radiographie wird zusammen fassend dargestellt Der relative Wert der Verzerrung wird als zuverlassigstes Mass ange sehen Die Berechnung der Schichtdicke sollte sich auf die Definition der relativen Verzerrung stutzen Es wurden experimentelle Tests vorgenommen um die mathematisch wieder gegebene Hypothese zu bestatigen ebenso wie die Richtigkeit des mathematischen Modells der Feinstrahl Rotations Radiographie welches von WELANDER (1974) gegeben worden ist

RESUME

Les auteurs rappellent la definition de l effacement en radiographie rotatoire avec un faisceau étroit Ils pensent que la mesure la plus fiable est celle de l effacement relatif Les calculs de l epaisseur de couches de coupes devraient etre bases sur la definition de l efface ment relatif Des tests experimentaux confirment l'hypothese presentee mathematiquement et confirment la validite du modele mathématique de la radiographie rotatoire avec faisceau etroit presente par WELANDER (1974)

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EFFECT IN VITRO OF IOGLYCAMIDE ON BLOOD PROTEINS AND PARAPROTEINS

J BRAUMAN H BRAUMAN B VAN CAMP and J MATHIEU

Five years after the introduction of ioglycamide as a contrast medium for cholegraphy death following gel formation of blood during the intravenous injection of the medium has been reported in a patient with Waldenström s disease (BAUER et coll 1974) The gel formation was reproduced in vitro by the same author with blood serum from 2 additional patients with IgM immunoglobulins The viscosity increased which does not occur in serum containing high quantities of IgA or IgG immunoglobulins The authors suggested that an immune reaction took place between the contrast medium and IgM immunoglobulins Ioglycamide is still used in radiology however although its use in the case of paraproteinemia is prohibited Since 1974 no similar accident has been reported As the binding of ioglycamide to proteins has not been analysed previously in vitro experiments were performed and the results are now reported

In a preliminary work ioglycamide was added to serum from subjects with Waldenstrom s disease and to an IgM commercial preparation (MATHIEU & BRAUMAN 1975) Reproducing the experimental conditions of BAUER no alteration of viscosity of the serum or of the commercial IgM occurred No immune reaction took place between IgM paraproteins and ioglycamide This observation shows that the gelatinizing phenomenon (BAUER et coll) does not invariably occur in IgM paraproteinemia

Submitted for publication 4 October 1976

Ioglycamide in vitro untersucht Die Viskositat war unverandert In keinem Fall war das mit Isotopen markierte Kontrastmittel zu der Paraproteine gebunden Diese Resultate stehen in Widerspruch zu jenen Angaben der Literatur die in Patienten mit Morbus Waldenstrom eine Veranderung des Plasma von Sol zu Gelzustand berichten

RÉSUMÉ

Aucune modification de viscosite du plasma ou sérum, après addition in vitro d ioglycamide n a ete observee chez 160 sujets normaux et chez 1 467 patients comportant 33 cas de paraproteinemie IgM dont 20 cas de maladie de Waldenstrom Le produit de contraste marque ne se lie dans aucun cas aux paraprotéines Ces resultats sont en contradiction avec la litterature mentionnant la prise en gel du plasma se produisant dans la maladie de Waldenström

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